A SYSTEM

OF

ELECTROTHERAPEUTICS

INTERNATIONAL CORRESPONDENCE SCHOOLS

SCRANTON, PA.

TECHNIQUE AND PHYSIOLOGY OF STATIC AND
OTHER HIGH-FREQUENCY CURRENTS

TECHNIQUE AND PHYSIOLOGY OF DIRECT CURRENTS

TECHNIQUE AND PHYSIOLOGY OF COIL-CURRENTS

SCHOOL OF ELECTROTHERAPEUTICS

FACULTY

W. F. BRADY, M. D.,
DEAN OF THE FACULTY.

Professor of Electrotherapeutics and Genito-Urinary Surgery.

WM. J. HERDMAN, M. D., LL. D.,
PROFESSOR OF NEUROLOGICAL ELECTROTHERAPEUTICS.

Professor of Diseases of the Mind and Nervous System, University of Michigan; Fellow
American Academy of Medicine; Member American Medical Association;
Ex-President American Electrotherapeutic Association.

S. H. MONELL, M. D.,
PROFESSOR OF STATIC ELECTRICITY.

Chief Instructor of New York School of Special Electrotherapeutics; Author of "Treatment
of Diseases by Electrical Currents," "Manual of Static Electricity in X-Ray and
Therapeutic Uses," "The Cure of Writers' Cramp and the Arm
Troubles of Telegraphers and Ball Players," etc., etc.

AUGUSTIN H. GOELET, M. D.,
PROFESSOR OF GYNECOLOGICAL ELECTROTHERAPEUTICS.

Professor of Gynecology in the New York School of Clinical Medicine; Member of the American
Medical Association; Ex-President of the American Electrotherapeutic Associ-
ation; Ex-President of the Society for Medical Progress; Member
of the Société Français d'Électrothérapie, etc., etc.

J. C. PRICE, M. D.,
PROFESSOR OF ELECTROTHERAPEUTICS AND ROENTGEN RAYS.

D. C. REUSCH, M. E.,
PROFESSOL OF ELECTROPHYSICS.

83908

CONTENTS.

CONTENTS.

PLATE I.

End View of Static Machine, Showing Rheostat a, Having Twenty-Five Buttons, Each Button Representing Five Ohms.

Technique and Physiology of Static

AND

Other High-Frequency Currents.

INTRODUCTION.

1. Static electricity is the first of the electric modalities that has been used in medicine. It was employed very frequently by physicians during the last half of the 18th century and the works published during that time on electrotherapy are well worth perusing.

The application of the discoveries of Galvani, Volta, and Faraday in the first half of the 19th century caused static electricity to be so much forgotten that Duchenne, Remak, Onimus, and Erb scarcely mention its use, or if they do mention it, it is simply as a very unimportant agent. The truth of the matter is that static electricity was discarded by physicians on account of the uncertainty and imperfection of the generators of static currents. The static machines then in use could not be relied on. Physicians of one hundred years ago understood and appreciated the value of static currents in medicine, but it too often happened that just when they most needed currents for treating patients, the static generator would not work at all. The currents from the voltaic pile and the magneto-electric generator were the ones generally used by the physician from 1800 to within comparatively modern times.

The modern revival of static electricity in medicine is due to

the labors of Vigouroux and d'Arthuis in France, of Stein in Germany, and of Morton and his students in this country. To the labors of these well-known teachers should be added the improvements made in the mechanical and electrical construction of static generators. The static machine of today can be relied on to produce an efficient current every day of the year, and the physician who understands how to care for and use it has an electric generator always at his command. We wish to state that static currents occupy an important place in modern electrotherapeutics.

Up to 1880 there is no mention made of static currents in electrotherapeutic literature. The question always was of general electrification, positive or negative, of breezes, sprays, and sparks. Between 1880 and 1891, Wm. J. Morton, M. D., of New York, described both the direct and the indirect Franklinic interrupted currents, and these currents are now generally known as **spark-gap** or **Morton currents**. The indirect Franklinic interrupted current is frequently described as the static induced current.

In 1893, S. H. Monell, M. D., described a modification of the direct Franklinic interrupted current under the name of *potential alternation.* In 1899, the technique of potential alternation was somewhat simplified by Wm. J. Morton, M. D., under the name of the electrostatic wave-current. This latter current has become very popular within a few years, due mostly to the writings of Doctors Morton and Snow. The electrostatic wave-current and potential alternation are both direct Franklinic interrupted currents, because the current as it is generated by the static machine is interrupted when applied to the patient. In the indirect Franklinic interrupted current, or the so-called static induced current, the current as generated by the static machine is utilized in charging the internal armatures of the Leyden jars, and the charges thereby induced on the external armatures are utilized in the treatment of the patient: the direct static current is interrupted in order to produce a secondary, or indirect, current in which the patient is placed.

In 1893, d'Arsonval published his classic studies on the physiological actions of the currents that are now usually described
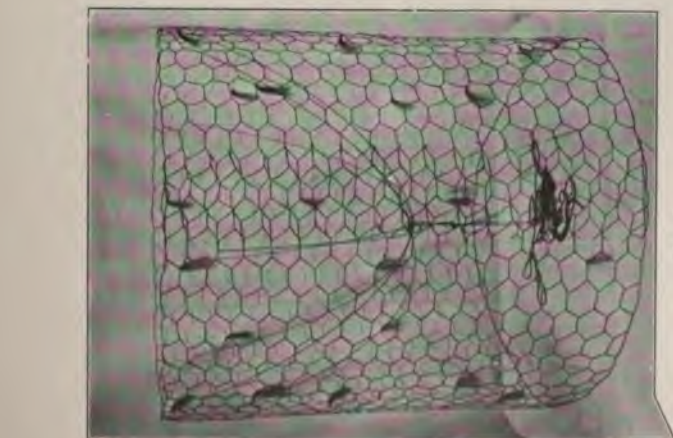
Fig. 3.
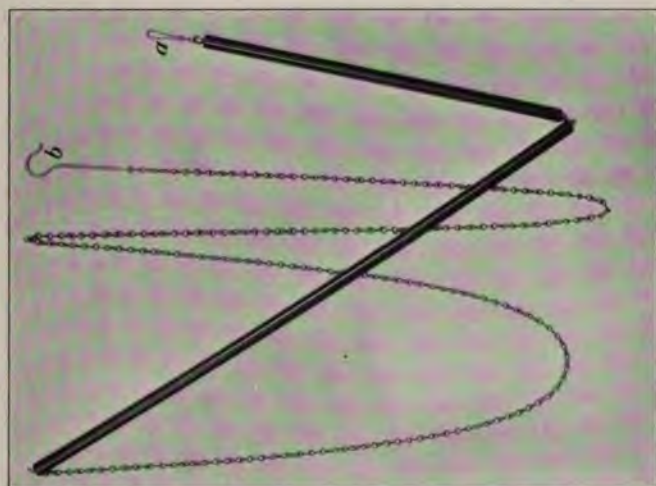
Static Electrodes.

Fig. 2.

Dr. Monell's Insulated Electrode Handler.

PLATE II.

Fig. 1.

Static Cage.

as high-frequency, or Tesla-d'Arsonval, currents. In this Section we shall consider the technique and physiological action of:
1. General electrification, positive and negative.
2. Breezes, sprays, and sparks.
3. The Franklinic interrupted current, direct and indirect.
4. Potential alternation.
5. Electrostatic wave-current.
6. High-frequency current of d'Arsonval.

STATIC MACHINES.

2. With reference to the composition of their revolving plates, **static machines** may be divided into two classes; namely, (1) *glass-plate machines;* (2) *mica-plate machines.* The **glass-plate machines** now generally used in electrotherapeutic and X-ray work have eight, ten, or twelve revolving plates, 28 or 30 inches in diameter. When the glass-plate machines are not constructed so as to be self-exciting, they are provided with a small Winshurst charger in the same case. Glass-plate machines are capable of running within limits of safety at about 400 revolutions per minute. Glass-plate machines require some agent, usually calcium chlorid or sulfuric acid, within the case in order to obtain from them their maximum of efficiency.

The four sizes of mica-plate machines on the market have two, four, six, and eight revolving mica plates; the glass plates are stationary. The sizes of these machines are as follows:
1. Four-plate static machines have two revolving mica plates 28 inches in diameter and two stationary glass plates 31 inches in diameter.
2. Eight-plate static machines have four revolving mica plates 28 inches in diameter and four stationary glass plates 31 inches in diameter.
3. Twelve-plate static machines have six revolving mica plates 28 inches in diameter and six stationary glass plates 31 inches in diameter.
4. Sixteen-plate static machines have eight revolving mica plates 28 inches in diameter and eight stationary glass plates 31 inches in diameter.

A mica-plate static machine can be run upwards of 2,000 revolutions per minute. It is claimed for mica plates that they remain dry and that they do not condense moisture under the most unfavorable atmospheric conditions; they therefore require no calcium chlorid or sulfuric acid within their case.

A static machine serves three purposes in a physician's office: It generates electric currents that are applied therapeutically; it generates ozone that is applied therapeutically; it is a first-class electric source for the generation of X-rays for diagnostic and therapeutic purposes. A good static machine in a physician's office will always be ready to supply an efficient current for therapeutic and X-ray purposes.

The electrical output of a static machine depends on the number and diameter of the plates and on the rapidity with which they are made to revolve.

THE HOLTZ INDUCTION-MACHINE.

3. Varieties of Holtz Induction-Machines.—There are obtainable today several sizes of Holtz induction-machines for therapeutic and X-ray purposes, but those in most common use are the 10-plate 28-inch machine, and the 12-plate 30-inch machine. The difference in price between these two machines is not much, but the latter is larger and more powerful than the former. They may be run by hand- or water-power, but a $\frac{1}{4}$-horsepower motor, if a street current is obtainable, will be found the most convenient and serviceable. A rheostat, (a) Plate I, of 150 or 175 ohms resistance will be required to regulate the motor. Means should be provided for cutting off the current, so that it does not heat the motor or rheostat when the machine is not in use. The room in which a static machine is placed should be large and dry. When first placed in a room the machine should be solidly and evenly fixed. On the proper position of the case depends the steady even motion of the machine, provided that the plates, combs, and internal parts are properly put together. Figs. 2 and 3, Plate II, illustrate the electrodes employed in the therapeutic uses of static currents.

PLATE III.

Method of Charging Machine.

20492

4. How to Keep the Plates Dry.—Ten pounds of `
calcium chlorid should be divided among three or four fireproof
dishes, and placed in an oven until the calcium chlorid is
thoroughly baked. The time required for the baking varies,
but the important point is to take care that it is thoroughly
done. The dishes are then placed within the case of the
machine, and the doors instantly closed and firmly secured
until it becomes again necessary to reopen the case. During
the winter, when the air of the room is dry and heated, the
calcium chlorid is not actually needed, yet the inside of the case
is a convenient place to keep it. During the spring and fall
months the dishes should be taken out of the case at least once
a month, rebaked in the oven, and then returned to their former
place. In the warm rainy weather of the summer it will be
advisable to repeat this process once every week. The condition
of the calcium chlorid will determine the necessity of rebaking.

A single 10-pound can of calcium chlorid will in this way
serve to keep the interior of the case free from moisture, and the
plates and conductor dry for 1 year, or longer.

5. How to Ground the Poles and Electrodes.—This
is readily done when the office is supplied with both gas and
water. In the absence of these, two iron pipes can be driven
into the ground in convenient places until they reach moisture.
Two separate groundings are advantageous—one for the prime
conductor not in use and the other for certain electrodes.
Having secured metallic conduction to the earth, either by
means of gas- and water-pipes or the two iron pipes driven into
the ground, the office terminals of these groundings may be
brought to a working distance from the machine by joining to
them a piece of stout copper wire. The copper wire may be
brought along the wall to within a short distance of the
machine and bent to terminate in a hook. A chain that accom-
panies every static machine is then attached to the copper wire,
and the free end of the chain is provided with a hook, by which
it is attached to the pole not in use, or to a convenient place on
the wall when the machine is not in service. Two grounding
connections are advantageous in general practice.

The metallic grounding for the electrode is obtained in the same manner. The chain of the electrode may be directly attached to a chandelier if it is of good conducting material. If the chandelier is not made of good conducting material, a piece of stout copper wire can be secured to the pipe as it leaves the ceiling and brought within reaching-distance of the operator, A gas-bracket on the side of the wall may be used in the same way.

6. Essential Points.—The essential points in the grounding of the prime conductor and various electrodes are:

1. That the connection with the earth is made by metallic pipes instead of merely dropping a chain on the office floor, as is done by many.

2. That the room terminals of the metallic pipes are brought by means of a piece of stout copper wire to a convenient working distance near the prime conductors and the operator. Two groundings are essential in order to obtain all the best results from the static machine. High-potential difference between the two static poles can only be secured by good metallic grounding. *This is one of the most important of the rudimentary principles of using static electricity in medicine. Many have failed to procure good results with fine machines simply through want of knowledge of this fact.*

7. The Platform.—The platform is supported on insulating glass rods 1 foot high, and is usually made of oak with natural-wood surface, which should be smooth. The platform conducts best without a coating of schellac, oil, or varnish, for they are bad conductors and interfere with the passage of electricity to the insulated patient. The corners of the platform are rounded, to lessen the tendency of the electric charge to escape. Moistening the surface of the platform will increase the conductivity, but this is better done by the use of a metallic foot-plate connected by a short piece of chain to the platform-rod.

8. The platform is usually placed some distance, about 2 feet, from the prime conductors. If the patient is too near the negative prime conductor, while the platform is connected with the positive pole, and the factors of a strong current and high

PLATE IV.

Self-Treatment—Static Sparks

resistance are present, it may prove disagreeable to the patient. In making all static applications, the operator must habituate himself to keeping out of sparking distance from the patient. Carelessness in moving about the platform will often result in giving the patient an unexpected shock, and in lessening his or her confidence in the skill of the operator.

The electric current is conveyed from the prime conductor to the platform along a metallic rod, curved at one extremity for attaching it to the sliding-pole, and terminating at the other extremity in a round ball, which rests on the platform. This metallic rod should be attached to the sliding-pole with the end of the crook pointing toward the platform.

9. Method of Conducting Current.—There are two methods of conducting the current in a direct manner from the prime conductor to the patient:

1. By placing the metallic conductor in the hands of the patient.

2. By placing a brass plate 15 or 16 inches square beneath the feet of the patient. One corner of this brass plate is perforated, to give attachment to a brass chain about 2 feet long. The metallic conductor may then rest on any part of the platform, and can be connected to the brass plate beneath the patient's feet by means of the chain.

Either of these methods gives direct metallic conduction, which affords the best method when it is desired to use the entire electric output of the machine. When the current is interrupted by sparks in any part of its circuit, the brass plate under the feet will sometimes prove disagreeable to the patient wearing shoes with thick soles and nails in the heels. To avoid this the rod may be held in the hands.

To determine whether or not the patient on the insulated platform is receiving the full current-strength coming from the machine, instruct him to approach his fingers to the conducting-rod between the platform and the prime conductor. If no sparking occurs on performing this, it shows that the potential of the patient and the prime conductor is the same, and that he is getting the entire current from the machine. If sparking

does occur, it demonstrates a difference of potential. The length of the sparking distance affords an accurate measurement of the amount of current-leakage.

10. How to Distinguish Polarity.—*First*, start the machine slowly in motion; and, with the sliding-poles about an inch apart, observe carefully the first spark that passes. The pole from which it starts is positive, and the one to which it goes is negative.

Second, with the machine in moderate motion, the spark-stream will have a violet color near the negative pole, and there will be a white handle of light coming from the positive pole when the spark-gap is an inch or two in length. With a long gap this is reversed.

Third, with the poles about 6 inches apart and the spark-stream compact, place a grounded electrode on one pole. This will conduct the current to the earth and stop the spark-stream if the pole is positive. If the grounded electrode is placed on the negative pole, the spark-stream will be increased in energy and more compact in appearance. This is a crucial and very easily performed test for determining polarity, and when correctly done is quick and infallible.

The fox-tail phenomenon is only seen on the positive side of the spark-stream. If the operator from the beginning trains his eye and ear to the motions and noises produced by his machine, he will always be able to determine without these tests what polarity he is using.

Fourth, take a stick of wood and bring it near the discharge balls while they are in sparking distance, the positive (+) electricity will follow the wood, the negative (−) will not.

Fifth, look at the combs between the plates: at the negative side you will see blue flames, at the positive only points. This sign is more valuable than the other four, because you can see it while the patient is on the platform and being treated.

11. How to Charge the Holtz Machine.—Without an initial charge the induction-machine is of course useless. This initial charge is now given by a small Wimshurst machine supplied for the purpose. The two poles of the small Wimshurst
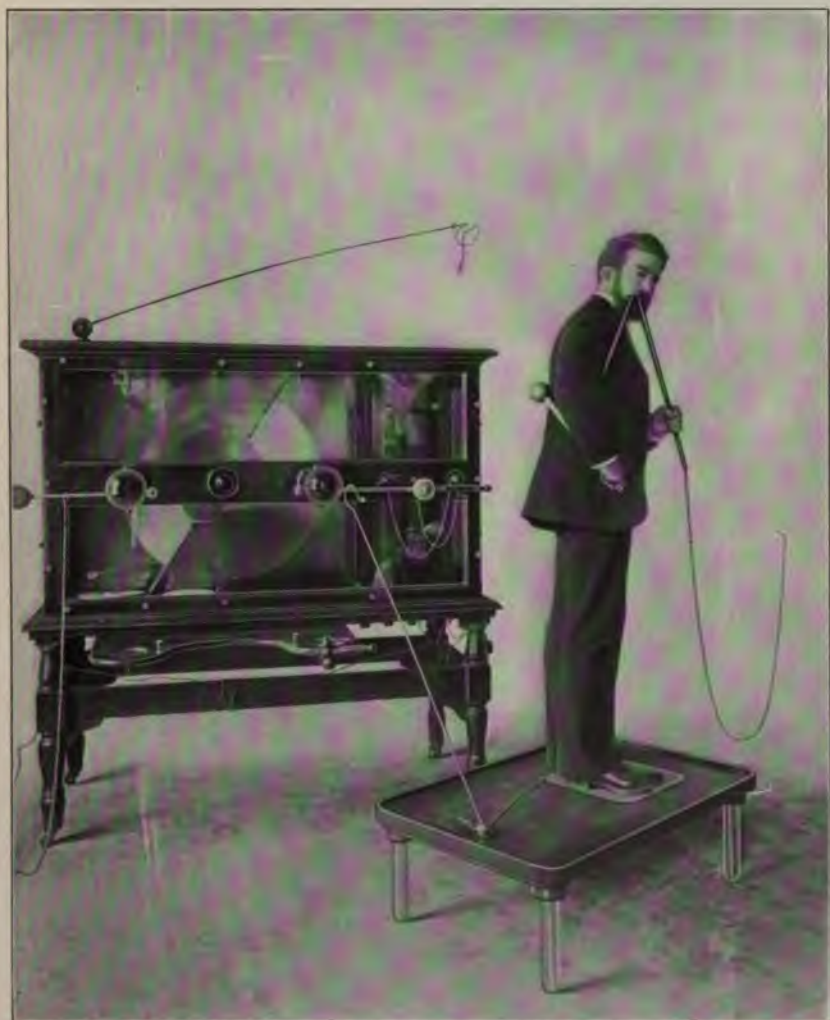
PLATE V.

Self-Treatment—Spinal Friction.

charger are connected by two metallic rods with the two poles of the induction-machine. Both sets of plates are now set in motion, and the small initial charge communicated by the Wimshurst is multiplied by the plates of the induction-machine into a current of high potential. This process usually requires about a second, but it may require a half-hour if the machines are neglected, damp, and in bad order. If the Wimshurst is of superior make, giving a spark of about 1 inch, the charging is usually rapidly accomplished. During the charging the sliding-poles are placed about an inch apart at first, then short-circuited to disconnect the charger, and then drawn wide apart. A good Holtz machine may run an entire winter with the original charge given at the beginning of the season. Even in summer it will not often discharge if the chlorid is kept dry. It is, however, not any trouble to excite the plates, and the fact that they occasionally discharge is no longer a drawback. Plate III illustrates method of charging the Holtz induction-machine. There are now self-charging Holtz machines. In fact every static machine can be made self-exciting or not.

12. **How to Discharge the Holtz Machine.**—Revolve the plates backward, with the sliding-poles gradually approaching each other until the sparking ceases. Now touch both poles with grounded electrodes. To demonstrate the success of this procedure, set the poles again in motion in the right direction. If the procedure is successful, no sparks will pass, and there will be no evidence of any current.

13. **Reversed Polarity.**—The Holtz machine rarely reverses its charge, and never during the treatment of a patient. When it occurs it does no harm. If the change of polarity is recognized, the operator can accommodate himself to the change by simply shifting the conducting-rod to the desired pole. A changed polarity may not always be convenient, on account of office arrangement and the formed habits of the operator in using his electrodes.

14. **How to Correct Reversed Polarity.**—1. The machine must first be thoroughly discharged, and then its positive end lifted slightly from the floor and let drop suddenly.

This will jar the plates. This can only be done with one of the smaller machines.

2. The case may be jarred by blows on its side or on the floor.

3. Tap a few times with a hammer on the outer end of the brass cross-rods supporting the upper set of diagonal combs.

To ascertain whether these procedures have been successful or not, it is only necessary to recharge the plates. If these procedures have not been successful, repeat them. It is not necessary to correct a reversal of the usual charge, but the above means can be employed when the operator prefers to do so.

These different manipulations—lifting the positive end of the machine and dropping it with a jar, blows upon the side and floor of the case, taps on the brass cross-rods supporting the upper set of diagonal combs—do no harm to the machine if carefully executed.

4. With the discharge rods widely separated and grounded, rotate the plates backward 5 or 6 times; then remove the groundings.

5. Set a Leyden jar in contact with either prime conductor and charge it by revolving the plates and separating the sliding-rods, then remove jar, being careful not to discharge it. Give the machine a few turns backward and touch the prime conductors with the hands or a grounded electrode to remove all electricity, then set jar back on machine and in contact with the prime conductor *opposite* the one from which it was taken, start the machine into action and the polarity will be changed.
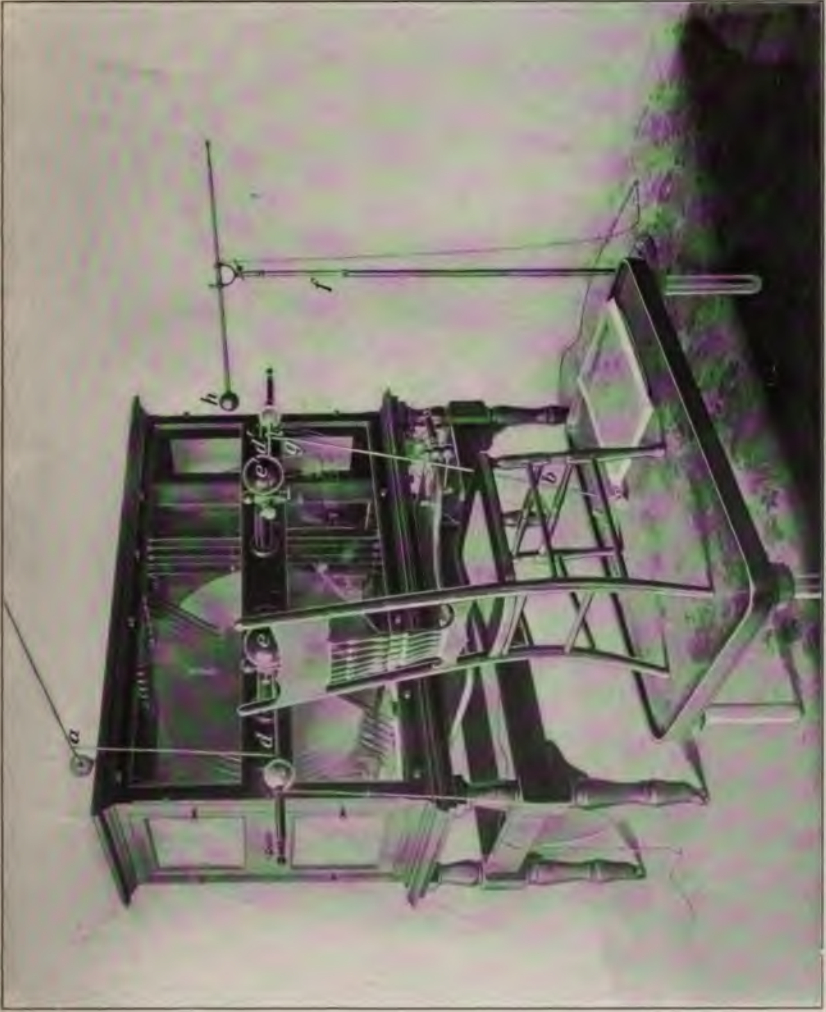
PLATE VI.

Potential Alternation.

PLATFORM METHODS.

15. Static treatment, in the insulating methods of its application, differs widely from the other varieties of electric currents. Well-moistened electrodes and rheostats are not in evidence. Disrobing, which causes so much trouble and loss of time in galvanic and faradic treatment, is entirely dispensed with. The patient steps upon the insulated platform in the same apparel that he or she wears on the street.

16. Character of Static Treatment.—With one exception every static treatment is *general.* The breeze, spray, or spark may be used to alter pathological conditions in localized portions of the body, but the fundamental principle of static treatment is *general electrification.* The insulated platform is an essential part of every static treatment, with the single exception of the indirect Franklinic interrupted current. Without it there would be no accumulation of electricity, no spark, no breeze, no spray. This may be easily verified by standing on the floor and placing one hand on the prime conductor. The current will pass through the body in its normal current-strength to the ground. There will be no evidence of accumulation such as is produced on the insulated platform. Sparks cannot be drawn from the body. The hair is not erect. None of the usual static effects are produced.

17. Accumulation.—Accumulation is therefore of vital importance in obtaining therapeutic results, and every care should be taken to make it as complete as possible. The insulated platform is provided with an ordinary chair devoid of all metallic ornamentation. A stool without a back is often very convenient, but a chair with an open back may be made to answer nearly all purposes. In special forms of treatment, particularly in cases of weak and debilitated patients, a reclining-chair or steamer-chair will be found very serviceable. It should be placed on the platform in such a way that the active

prime conductor is opposite the head. Attention to this will avoid irritation to the patient from woolen clothing with an opposite breeze.

The patient need rarely be requested to divest himself or herself of metallic ornaments to avoid annoyance during treatment. Hairpins, corsets, buckles, eye-glasses, watches, and jewelry only cause irritation when a breeze or spray is given over them with a strong current, the positive pole to the platform, and with but partial skill. It does not affect a watch.

SELF-TREATMENT.

18. Before performing operations on the living body, the surgeon acquires confidence in himself and skill in his manipulations by operating on the cadaver. Skill and confidence in static applications are most quickly acquired by self-treatment. Plates IV and V illustrate the technique of self-treatment by static currents. The physician can in this manner test the sensory and motor effects of the different kinds of sparks on almost any part of his body. The sensory and motor effects of the long percussive spark and of the short frictional spark, positive or negative, on parts well cushioned, and also on those unprotected by fat and muscles, should be studied and compared. The sensory effects of the breeze and spray, positive or negative, interrupted and continuous, on the bare skin and through fabrics having different resistances, should be carefully studied by the physician on his own body, if he would succeed in applying the breeze or spray with pleasant and beneficial results to his patient.

This method of self-treatment is strongly recommended to the student before he uses static currents on his patients, as it is just as important that he acquire an accurate knowledge of the sensory and motor effects of these currents in order to obtain success as it is for the surgeon to practice operating on the cadaver.

EXPERIMENT I.—Stand on the platform as illustrated in Plate IV. With the plates in moderate motion, deliver a few
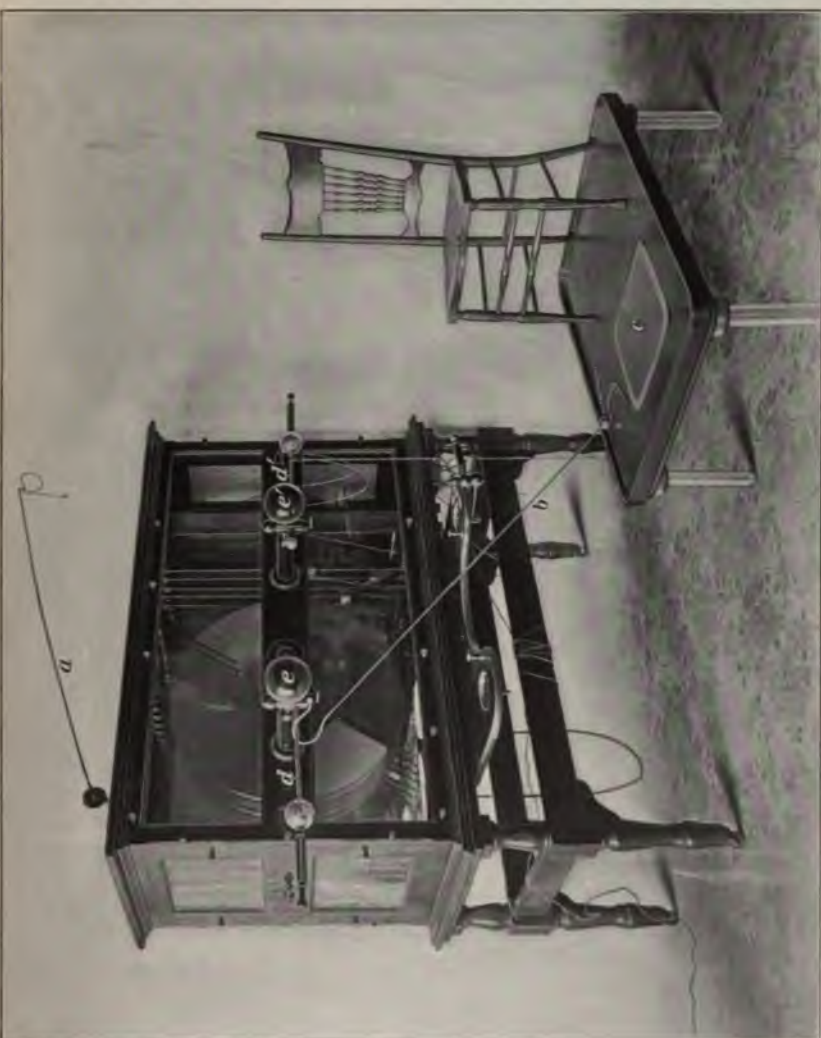
PLATE VII.

Simple Positive Electrification.

sparks on the thickest part of the muscles of the leg and then on the forearm 1 inch above the wrist-joint. The positive spark is less penetrating and is milder in its sensory effect than the negative, and should be tried first. Now connect the platform with the positive prime conductor and repeat the same process. The difference between the positive and the negative sparks is due to the higher voltage of positive insulation. Before causing the plates to revolve rapidly, rub the ball electrode briskly over the muscles of the leg and up and down the spinal column, observing the effects produced.

EXPERIMENT 2.—Connect the platform with the positive prime conductor, and sit on the platform chair with the breeze-electrode in your hand. Ground the electrode and the conductor not in use. First test the effect of breeze and spray on the dorsum of the bare hand. Next cover the hand with loosely woven woolen goods and repeat the same process, testing breeze and spray. Different fabrics may be thus tested until the physician has satisfied himself that he is familiar with the effects of different resistances when using breeze or spray with positive electrification. This is the only way by which the physician can learn to develop the tonic, sedative, counter-irritant, and rubefacient effects of the negative spray. The bland sedative qualities of the positive spray often elicit expressions of gratitude, yet the counter-irritant rubefacient effects of the negative spray are more closely connected with the pathological lesions of chronic maladies.

Both the positive and the negative breezes are bland and sedative when applied to the bare skin, but the negative breeze through the required resistance can be made to blister the skin with a few minutes' application.

EXPERIMENT 3.—Always ground the electrode and the prime conductor not in use. Stand on the platform as illustrated in Plate IV, but do not ground either the electrode or the pole in use. With the plates in rapid motion, apply a few sparks to the quadriceps muscle. Now ground the pole not in use and also the electrode, and deliver a few sparks as before, and note the effects of both applications.

EXPERIMENT 4.—With the machine arranged for potential alternation, as illustrated in Plate VI, start the plates in rapid motion, and separate the ball of the electrode in the movable stand from the terminal of the "shepherd's crook" connected to the positive prime conductor to a distance of about 4 inches, and observe carefully the thickness of the spark-stream. Now take the grounding off the fixed electrode, and the spark-stream will be diminished one-half. This is a very important experiment, and will demonstrate to the student the advantage of providing metallic grounding for the electrode in order to obtain maximum current-strength, and, therefore, maximum therapeutic results.

SIMPLE POSITIVE ELECTRIFICATION.

19. Method of Procedure.—Seat the patient on the platform and connect the positive pole *d* with the platform by means of the usual metallic rod *b*. The patient's feet are placed on the brass plate *c* that is connected with the metallic conducting-rod *b* by means of a chain. The negative pole *d'* is grounded. Before setting the plates in motion, separate the sliding-poles to their greatest extent, otherwise disagreeable sparking will take place between the brass plate and the soles of the patient's feet. During simple electrification, either positive or negative, the sliding-poles should be always separated to their greatest extent. It is only when Leyden jar currents are used that the poles are approximated. Simple positive electrification is illustrated in Plate VII.

20. Character of Simple Positive Electrification. Simple positive electrification, on account of its higher voltage, is much more energetic than simple negative electrification. It subjects the patient to a stronger and more energetic current, and is correspondingly more valuable as a therapeutic agent. *With a powerful static machine in good working order, the choice of poles makes little difference; and, by regulating the dose, nearly equal effects can be produced. With a small machine giving only a small electrical output, it may be always necessary to use the higher-potential polarity.* With a good electric output and proper technique, both polarities may be made to produce almost

PLATE VIII.

Positive Electrification.

similar effects. If the negative breeze with positive insulation should prove too irritating, the irritation will be moderated by diminishing the current-resistance. The negative breeze is not irritating through cotton material or on bare skin. In the various static applications the *resistance of the clothing* should be carefully studied, and it can be increased or decreased as indications require.

21. The Advantages.—Simple positive electrification has a wide field of usefulness. It is perhaps the great tonic of the future. It is simple and easy to administer, and envelops the patient in an atmosphere of positive electricity. With the machine in rapid motion, large quantities of ozone are also generated. This is inhaled by the patient, and is considered by some to heighten the tonic effects of electricity. The treatment is applicable to any age, to the infant in the mother's arms and to the extreme limits of old age. In cases of simple positive electrification, with no local modifications in method, several persons may be treated at the same time on one large platform. In order to obtain the best therapeutic results, a maximum current is necessary in this form of treatment, and the patient should rest quietly. Conversation is not beneficial during the séance, as it keeps the nervous system more or less excited.

Plate VIII illustrates a very useful method of administering simple positive electrification. The patient holds the connecting-chain in his hand and reclines on a steamer-chair. This puts the patient at complete rest, and enables him, when debilitated from disease, to obtain the maximum benefit from each electrification without fatigue.

SIMPLE NEGATIVE ELECTRIFICATION.

22. Character of the Treatment.—The platform is connected with the negative pole by the conducting-rod. The chain attached to the copper wire leading from the water- or gas-pipe is hooked to the positive pole. The metal plate is placed under the patient's feet or he may hold the conducting-rod in his hand. There is no need to apprehend annoyance during simple negative electrification, on account of the lower

voltage of the current. There is seldom any sparking within the case, and no irritating breezes from without. This method of treatment affords a safe means of beginning static treatment in cases of nervous and easily excited patients. Every form of static treatment should be administered with studied care, in order to give to the patient the best therapeutic results with a minimum amount of annoyance. Indeed, it should be the aim of the operator to make every treatment as agreeable and pleasant to his patient as is compatible with thorough energetic treatment.

These two forms of treatment are often called *static insulation* or *static baths*. It is simple electrification *continuous*.

23. Physiological Effects.—A patient placed on an insulating platform and connected with one pole of a static machine acquires the same potential as the machine itself: electricity escapes from all the prominences of his body and he is traversed by an electric current of high potential. The effects on the sensory nerves of the patient are reduced to a very feeble sensation and there is absolutely no reaction of motor nerves and muscles. What then takes place within the tissues of the patient during the general static electrification, positive or negative, or does not the organism react to this mode of electrification?

This question has been considerably elucidated, thanks to the researches of Vigouroux, d'Arsonval, Morton, Truchot, Bordier, etc. We shall examine successively the different functions affected by general electrification.

The pulse is increased in frequency and may exceed the normal by 20 per cent. The acceleration of the pulse is not limited to the duration of the séance; it may persist for several hours. After a number of treatments by general static electrification the frequency of the pulse maintains itself for 7 or 8 days.

Arterial tension is increased; all investigators agree on this point. Charcot demonstrated the influence of general electrification on the tension of the arteries in the following manner: A patient who had just been bled and for whom the flow of blood had just been stopped, was placed on an insulated
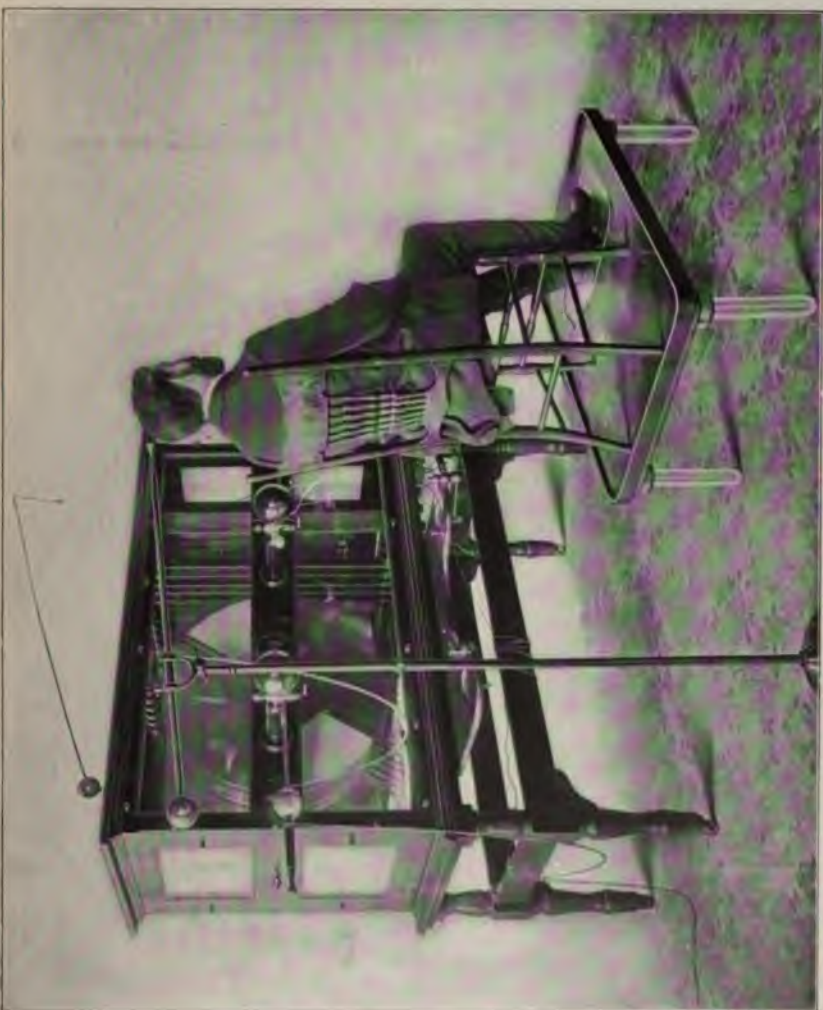
PLATE IX.

Stationary Breeze to Occiput.

platform in connection with one pole of a static machine: the blood recommenced to flow.

The central temperature is increased. Vigouroux estimates this increase at about .3° F. After electrification the temperature returns slowly to the normal. M. Damian claims that positive insulation increases the temperature more than negative insulation.

D'Arsonval has measured the respiratory capacity in animals and man before and after general electrification. If one measures the oxygen absorbed and the carbon dioxid exhaled, there will be found to be a sensible increase in their quantities as a result of general electrification. D'Arsonval has found that the respiratory capacity of the blood increases from one-tenth to one-eighth during static insulation. Ozone may, however, be an important factor in the oxidation of blood corpuscles. The secretion of the sudoriferous glands is also increased during static insulation. Not infrequently one sees the hands and forehead of patients become moist with perspiration during the administration of general electrification.

The most important secretion to consider is evidently the urine. For the ancient authors static electrification increased all secretions, the saliva, the sweat, the tears. D'Arsonval found a considerable increase in the amount of urea for 24 hours. Uric acid and phosphoric acid are also increased. The volume of urine is not sensibly increased.

24. Dynamometric Action.—Truchot measured the dynamometric force of his right hand before and after static insulation and invariably found an increase of 2 Kilos.

25. Action on Digestion.—Under the influence of static electrification the digestive functions are accelerated and the appetite is considerably increased.

There can be no doubt then that static electrification increases the pulse rate and raises arterial tension; that respiratory combustion is augmented; and that all the secretions of the body are increased in activity.

One can easily comprehend, then, how static electrification, when properly administered and when the séances are

sufficiently separated from one another, produces favorable results by facilitating oxidations and by increasing the amount of urea excreted, and how they can, when wrongly administered and too frequently repeated, overreach their mark and diminish the urea, and at the same time increase the excretion of other nitrogenous compounds. Static electrification should therefore be administered with circumspection, and one should not say that if it does no good it can do no harm.

LOCAL METHODS.

26. Function.—The two methods of static treatment already described act on the entire system without selecting any special organ or any special symptom on which to localize their therapeutic properties. The methods referred to expend their influence alike on sound and healthy tissues, on organs whose functions are normal, as well as on those whose organic physiology is well-nigh destroyed. The most salient fact of static therapeutics is that each individual submitted to its action receives, during the entire séance, the potential effects of general treatment, and that any special portion of his or her body, whether central or peripheral, may at the same time be modified in its function by local static methods. Nothing like this is possible with the therapeutic methods employed in treating disease with galvanic and faradic currents. The action of *local* static applications exerts a powerful influence far beyond the area on which it falls. The surface stimulation of sensory nerves, as has been demonstrated by Doctor Hodges, is transported to the central ganglia, where it produces lasting effects. Locomotor ataxia in its first and second stages is thus treated by local static methods, and in the great majority of cases the malady is for a time arrested. This can be explained in no other way than by assuming the transmission of peripheral stimuli to the central ganglia and the establishment there of enduring nutritional effects.

27. Kinds.—The local static methods in the order of their therapeutic properties are the *breeze*, the *spray*, and the *spark*. The breeze and the spray are convective discharges; the spark

PLATE X.

Positive Electrification—Stationary Negative Breeze to Head.

for by the lower negative insulation employed in its use. The main difference between the two poles of the static machine is that of a greater and lesser potential in the same current-action. With the skilled use of the electrodes, and the proper disposition of attractions and resistances, one pole may be made to produce nearly all the effects of the other. Naturally, in simple positive electrification, on account of the higher voltage of the current, the metabolic, nutritive, and other properties of high-potential high-frequency currents will be more pronounced than in simple negative electrification.

THE NEGATIVE STATIC BREEZE.

30. Method of Procedure.—The positive pole is connected with the platform and the negative pole is grounded. The negative breeze may be administered in the same manner as the positive. It may be continuous or interrupted, movable or stationary. On account of the higher voltage of positive insulation, attraction and resistance must be carefully observed. Through linen and cotton fabrics and on the bare skin the negative breeze is cool and sedative, but it may be made highly stimulant and counter-irritant when the skilled operator wishes to produce such effects.

When the hair is very thick, this form of head-breeze with positive insulation may be unbearable. By the patient continually shifting the position of his head or by keeping the brass-pointed electrode in motion, the negative breeze may be used without causing discomfort when indications demand it. Metal hairpins should be changed for vulcanite. Steel corset-blades will also cause a burning, disagreeable sensation with the negative breeze. In all these cases the essential thing needed to bear in mind is correct regulation of the dose.

31. Nature of Negative Breeze.—The negative breeze, like the positive, is cooling and sedative when applied to the bare skin, or through linen or cotton materials, but it may be rendered strongly irritant in its action by interposing resistance. Applied through loosely woven woolen fabrics it is a very efficient rubefacient and counter-irritant, reddening the skin

PLATE XI.

Stationary Breeze to Forehead.

20492

and causing a sensation of warmth that lasts for some time after the séance is completed.   In this way it rapidly relieves neuralgias and the various rheumatic muscular pains.

Cold extremities, sluggish circulation, hepatic, abdominal, and pelvic pains are amenable and frequently yield to this form of treatment. The rubefacient effects may be moderated by slowing the machine, or by leaking off, through the foot on the platform, some of the positive charge.   The irritant effects are increased by increasing the motion of the plates, or, better still, by interrupting the current between the prime conductor and the patient.

32. Points to be Noted.—The principal points to be remembered in administering the negative breeze are:

1.   It is cooling, sedative, and agreeable when applied to the bare skin or through cotton and linen materials.

2.   It is counter-irritant and rubefacient when applied through fabrics (like wool) offering high resistance.

3.   Vulcanite hairpins should be substituted for metal ones when a head-breeze is given, and, as far as it is convenient to the patient, all metallic objects should be removed from the person when they interfere locally with the comfort of the breeze.

4.   In giving either the positive or the negative breeze, the electrode must be made to adjust the dosage by regulating the distance from the patient according to the effect desired.

5.   On account of the prickly burning sensation produced by the negative breeze, when applied through resistances, the electrode should be manipulated over the part treated in such a way as to produce the exact effect desired.

6.   It must be remembered that the negative breeze is administered with the higher-potential insulation, and that it can be readily moderated by slowing the machine or by leaking off some of the charge by placing the foot on the platform.

Both forms of breeze, the positive and the negative, are capable of rendering valuable service in daily practice, particularly in cases of minor ailments; but the negative breeze, when used without sufficient care or sufficient knowledge, may prove very disagreeable to the patient.   Plate X illustrates technique of applying stationary negative breeze to head.

THE STATIC SPRAY, POSITIVE AND NEGATIVE.

33. Character of the Static Spray.—The breeze and the spray are convective discharges. The spray is simply a more intense breeze, discharged with the electrode closer to the patient. The breeze discloses no visible change in the atmosphere between the brass-pointed electrode and the surface of the patient's body; yet an electrified current of air is passing from one to the other. In any form of discharge, a circuit is constituted, static electricity becomes kinetic, and a current is flowing. The static spray, positive or negative, throws a convective shower of *visible* electrified particles of air from the brass-pointed electrode to the surface of the body of the individual treated. A more or less intense bluish stream of electrified air is seen passing from one to the other when the room is darkened a little. Neither the breeze nor the spray has the power of contracting muscles, and no muscle-contracting effects can be expected from them. The spray is stronger and more energetic in its action and therapeutic qualities than the breeze. It intensifies all the effects produced by the breeze. It is more sedative and calming than the breeze, when sedative and calming effects are desired; or it may be rendered more counter-irritant and rubefacient when these latter effects are the indications of treatment. It is used to relieve the same symptoms and treat the same diseases as the breeze. It will well repay a great deal of practice to perfect your skill.

Plates XI and XII illustrate the technique of administering breeze or spray. Plate XI shows stationary breeze or spray applied to forehead. When using the positive breeze it is well to remember that the positive electrode gives off sparks with great facility and may easily frighten a nervous patient. By carefully observing the point or points of the electrode, this accident may be avoided. Plate XII illustrates movable breeze or spray to forehead.

Plate XIII illustrates the technique of the movable negative spray applied to the thorax. A piece of woolen material is placed on the chest to obtain rubefacient and counter-irritant effects. This is a very valuable application in cases of

PLATE XII.

Movable Negative Spray to Forehead.

29492

PLATE XIII.

Movable Negative Spray to Thorax.

PLATE XIV.

Movable Spray to Occiput.

20492

chronic bronchitis and asthma. The energy of the spray may be much increased by interrupting the current in the following manner:

The patient takes the conducting-rod in his hand, and rests one extremity of it on the frame of the case so that it will be about 1 inch from the prime conductor in use. This will interrupt the current between the patient and the prime conductor, and will intensify the effects of either breeze or spray. The counter-irritant effects of the spray are much increased by interrupting the current in the manner described, and by bringing the electrode so close to the body that fine, needle-like sparks mingle with the spray.

Plate XIV illustrates movable negative spray to occiput. When the skull is thickly covered with hair, the negative breeze is irritating, and should be kept moving to be bearable. When the hair is thin or absent, the effect is bland and sedative.

When for any reason a counter-irritant, rubefacient, nutritive effect in the ankle, knee, or any joint is required, the technique shown in Plate XV is a rapid and effective method of treatment. With the proper resistance interposed, the counter-irritant nutritive effects can be regulated with precision. The joint is covered with woolen material, the foot rests on a hassock. The large breeze-electrode is slowly manipulated all around the joint until the desired effect is produced.

34. Physiological Effects.—The electrostatic breeze and spray modify the radiating capacity of the skin, reduce its temperature, and produce important vasomotor phenomena. The small vessels of the skin are contracted under their influence. They have the property of increasing the reparative processes in cutaneous lesions and of calming sensory phenomena, pruritus, and pain.

Bordier has demonstrated that under the influence of the breeze or spray important vasomotor phenomena take place, and that these differ according to the polarity employed. The negative breeze or spray lowers the cutaneous temperature more than the positive breeze or spray. This reduction of temperature continues after the termination of the séance, and then the

temperature returns very slowly to normal.   What is particularly interesting here is that the reduction of temperature is equal to the amount of heat radiated from the skin, as measured by the thermometer.   This local reduction of temperature explains the sensation of cold that one experiences under the influence of the breeze or spray.   The surface of the skin submitted to this influence of breeze or spray preserves the odor of ozone for several hours.

THE STATIC SPARK, POSITIVE AND NEGATIVE.

35.   The Percussive Spark.—A spark is given by throwing a ball electrode, with a quick movement, to a point so near the body that a disruptive discharge or spark takes place.   Static sparks are of two kinds—percussive and frictional. A **percussive spark** is a single discharge.   It is a thick, strong, clear-cut spark, varying from 1 inch to 6 inches in length. A long, thin spark is more burning and penetrating.   To give the precussive spark, a large brass-ball electrode is used.   (See Plate XVI.)   The brass-pointed electrode may be used to administer the breeze, spray, or spark.   At a certain distance it throws off a breeze; when placed a little nearer, the breeze will be changed into a spray; and held still nearer, spray and sparks will mingle together.   By throwing with a quick movement the brass-pointed electrode to a certain distance from the body, long thin sparks can be given off by an expert, but the ball is usually employed for sparks.

36.   The Frictional Spark.—The frictional spark is given by rubbing any metallic electrode over the surface of the body.   When this is done, a series of electrical discharges takes place.   These discharges consist of a number of fine minute sparks, varying in length from $\frac{1}{8}$ to $\frac{1}{4}$ inch, according to the thickness of the clothing.   The frictional spark may also be given by covering the brass-ball electrode with flannel, and then rubbing it over the surface of the bare skin.   The sparks in this case will have a length corresponding to the thickness of the flannel.   The positive spark is always milder and less energetic than the negative, because given with negative insulation.

PLATE XV.

Movable Negative Spray to Ankle.

PLATE XVI.

Percussive Sparks to Quadriceps Muscle.

20492

The dosage for sparks may be regulated like that for the breeze or spray. The current may be interrupted or continuous. The machine may be made to go fast or slow as desired, and part of the charge may be leaked off by placing the foot on the platform when it is desired to give a very mild spark.

When using frictional sparks for any purpose, their application may be made much more agreeable by placing the electrode on the part to be treated before the machine is started into action. By using this method, frictional sparks may be so regulated that their effects vary from an agreeable feeling of heat to the most intense sensory effects desired.

Plate XVII shows the ball electrode placed on the spinal region before the plates are set in motion. After each frictional application the machine should be stopped, and the grounded electrode placed for a moment on the platform before renewing the treatment. The ball electrode should be moved rapidly up and down the spinal column for about $\frac{1}{2}$ minute. The time of the application is regulated by closely observing the patient.

37. Precautions to be Taken.—The beginner in static methods will, if not very careful, administer sparks when it is not his desire to do so. Carelessly approaching too near the platform, or want of skill in using the electrodes, will often result in a spark. To give the breeze or spray, premeditation and skill are always required, for without either of these a luckless spark may often occur. The tendency of well-nigh all beginners in static technique is to indulge too freely in the use of static sparks. It is not an unusual thing to see a patient dance about on the insulated platform under the repeated stimuli of long percussive sparks, when a mild, bland, and agreeable application would perform all the therapeutic work. A spark should never be given except in response to a clearly based indication. When spark-treatment is necessary, a mild spark may fulfil all the indications. *Never give a long strong spark when a short mild one will do the work.* A patient should always be prepared for a spark-administration by a fairly clear knowledge of what he is to expect. It is a point of practical importance to reserve spark-treatment until you have gained

the confidence of your patient. Before giving the spark, explain to him the sensation he is about to experience. For the first treatment it is advisable to insulate the patient negatively and deliver the spark on some part well cushioned with soft tissues. This will break its force. There are certain parts of the body on which sparks are not given. Generally the face and head are avoided, but for special indications, mild sparks are even given on these parts, and with very good results. The breasts, both in the male and the female, and particularly the nipples, are very sensitive, and should, in general, be avoided when sparks are being given. The back of the hand, the dorsum of the foot, finger-nails, toe-nails, and bony prominences all over the body should as a rule be avoided. When, however, these various parts are the seat of disease and call for special treatment, the spark may be administered with decided benefit.

38. Function of the Spark.—The spark is the most active and far-reaching in its therapeutic results of all the static methods. A few well-directed, thick, percussive sparks delivered on the soles of the feet of an ataxic patient may bring back sensation that has been lost for months. Each successive treatment lengthens the time during which the returned sensation remains. It stimulates nutrition and the functions of the central nerve-cells. Chronic indurations and exudations are partly resolved and absorbed by it, but it is not equal to galvanism here. It is the remedy, par excellence, for rheumatism, hysteria, and gout. Sciatica— acute, subacute, or chronic— yields more readily to static treatment than any other known remedy. Weak and sluggish muscles are given renewed vigor; muscles and tendons long contracted are loosened and relaxed. It regulates the functions of nerves and muscles and also of the visceral organs.

39. Muscular Effect of the Spark.—The spark produces very strong and widespread muscular contraction. This increases molecular change and aids nutrition, local and general. Sparks rapidly following one another on the same spot cause unnecessary pain, and it is therefore better to administer them
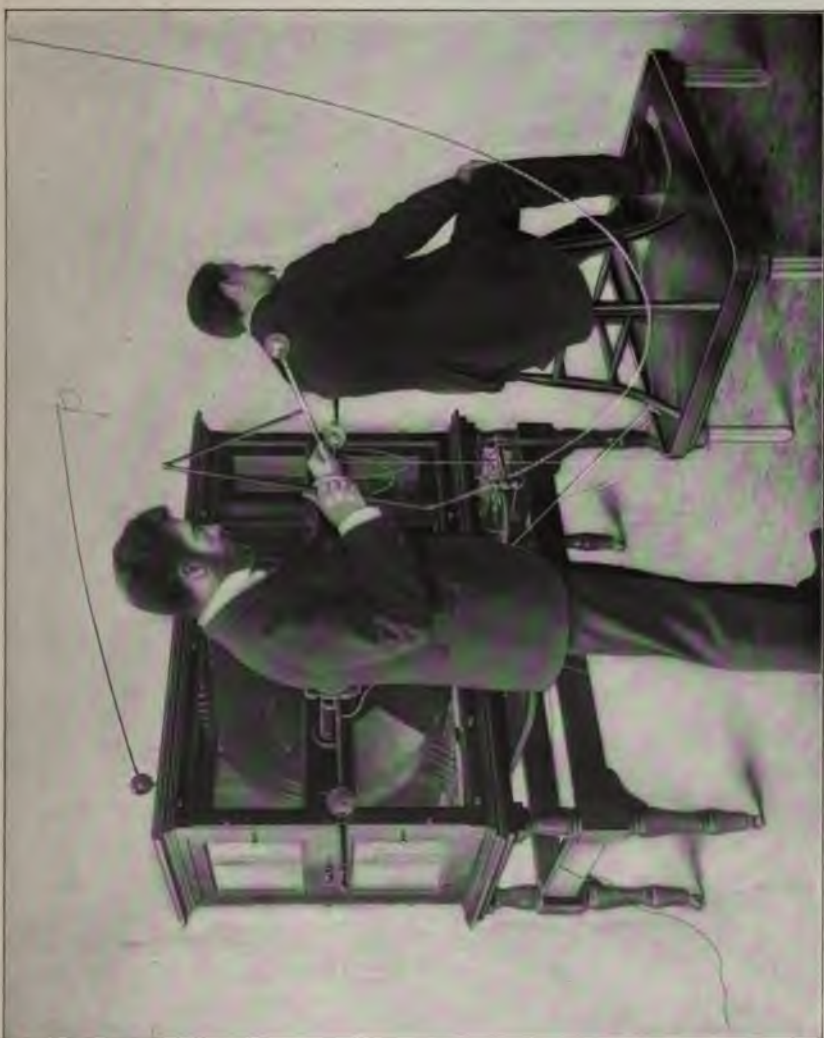
PLATE XVII.

Frictional Sparks to Spine.

PLATE XVIII.

Applying Sparks to Perineum.

with an interval of time and a change of base. A shower of sparks is painful and annoying, and should not be practiced.

Muscles may also be healthfully exercised without the annoyance of sparks applied to the skin. To do this, place an electrode over the motor points of the muscles to be exercised, and by means of a chain connect the electrode to the prime conductor. Now, by applying sparks to the prime conductor, the muscles are very vigorously contracted. Either hand may be placed in a jar of water containing an electrode connected with the prime conductor. By applying slow sparks to the prime conductor the whole arm is vigorously exercised.

40. Frictional Sparks.—Static technique may be modified in this manner so that any group or groups of muscles may be slowly or rapidly contracted, producing the physiological action of the slowly interrupted faradic current or all the vaso-constrictor effects of the rapidy interrupted fine-coil current. The frictional sparks are used for their counter-irritative and rubefacient effects. They are used in treating anesthesia and other altered conditions of sensation. In general they may be used whenever a counter-irritant is indicated. Their influence extends far beyond the reddened skin. They are used to combat hepatic, abdominal, and ovarian pain. Reflex pain of all kinds is often readily subdued by vigorous friction with the large brass-ball electrode over the regions to which the pains are referred.

The importance of sparks, frictional and percussive, to the perineum is based on the clinical results obtained and on the physiology of the nerves of the perineum. Plate XVIII shows the method of applying percussive sparks to the perineum, and Plate XIX the method of applying frictional sparks to the perineum. Both these methods require practice in the use of static electrodes, and might easily prove disastrous in the hands of a novice.

To the beginner in static methods, the electrode of Doctor Morton is especially recommended. Even with this electrode it is safer to have the plates in slow motion and leak off some of the current through the foot on the platform. With the ball

electrode, it requires considerable practice to apply either frictional or percussive sparks to the perineum.

Sparks, frictional and percussive, constitute the best therapeutic application of static currents in the hands of a skilful operator. They will, however, in many cases prove unsatisfactory unless employed with due regard to their effects and therapeutic indications. When sciatica, lumbago, or pain in the shoulder-joint does not yield to ordinary treatment, frictional or percussive sparks should be applied when the muscles are placed in that position which causes most pain. Plates XX, XXI, and XXII are given to illustrate postural treatment in the relief of pain. Pain will often yield to sparks applied in this position when it would not if the patient were quietly sitting on the platform-chair.

41. Physiological Effects.—The action of sparks is multiple. They influence sensibility and determine motor and vasomotor phenomena. A spark produces a burning sensation accompanied by shock. With very small sparks there is simply a burning sensation. The longer the sparks and the higher their potential, the more energetic is the shock or muscular contraction.

Eulenburg has studied the local actions of sparks with regard to cutaneous sensibility. He has concluded that long sparks produce a zone of hyperesthesia with a pallor of the skin to which the spark is applied. Sometimes sparks reduce the sensibility and produce redness of the skin. Short sparks rapidly succeeding each other diminish sensibility.

It is very important to understand the vasomotor phenomena produced by sparks, because they enable us to understand the mechanism of their therapeutic action, which certain physicians are still disposed to attribute to suggestion. There is always an elevation of temperature of the cutaneous surface to which sparks are applied. Positive sparks affect the vasomotor nerves more energetically than negative sparks. The surface of the skin to which sparks are applied first become pale, but this pallor is soon replaced by redness. If sparks are applied for several minutes to the same point, in the course of several hours

PLATE XIX.

Frictional Sparks to Perineum.

PLATE XX.

Posture in Treatment of Shoulder-Joint Pain.

20492

a blister will appear, which leaves, after its disappearance, an area of brown discoloration. In certain pathological states, notably in exopthalmic goiter, vasomotor effects are so accentuated that the name of dermographism has been given to the signs that can be traced by means of sparks applied to the skin.

If sparks are applied to a muscle or to the motor points and if the sparks are sufficiently separated from each other, individual muscular contractions are produced; if the sparks rapidly succeed each other, tetanic contractions are produced. This method of muscular excitation is increasing in professional favor both in electrodiagnosis and in electrotherapy of certain diseases. The muscular contraction produced by a static spark depends (a) on the polarity of the spark, (b) on its length, (c) on its diameter, and (d) on the density of electric excitation.

The contraction caused by the negative spark is stronger than that caused by the positive. Static sparks in their polar action resemble closely the polar action of galvanic currents. The energy of a muscular contraction produced by a static spark does not increase simply with the length of the spark, but is proportional to the square of the spark length.

The energy of a muscle contraction is also proportional to the diameter of the electrode employed.

M. Aubert has investigated the influence of sparks on cutaneous absorption. A compress, saturated with a solution of pilocarpin, was placed on the anterior aspect of his arm. At different times negative and positive sparks were applied to the compress with the result that positive sparks forced the alkaloid into the tissues while negative sparks had no appreciable effect on absorption.

It should be remembered that while certain parts of the body are submitted to the physiological effects of the breeze, spray, or spark, the entire organism is under the physiological influence of general electrification, either positive or negative.

STATIC CAGE.

42. Principles of Operation.—This is a form of static treatment introduced within recent years. It involves and extends the principle of the static breeze. From a single brass-pointed electrode, a single current of electrified air is projected to the surface of the patient's body. Multiplying the number of points increases the number of currents, but diminishes current-density. A breeze coming from twenty or more points is, of course, much more diffused than when concentrated on one single point, and is correspondingly more bland and sedative in its effects. The static cage (see Fig. 1, Plate II) would therefore be simply a question of current-density applied in the administration of a static breeze. Instead of presenting a single metallic point to the surface of the body, the static cage simply surrounds the entire body with metallic points, one in close juxtaposition to the other.

43. Method of Using Static Cage.—The static cage may be used in the following two methods: (1) The patient is insulated negatively and treated with a continuous or oscillating breeze. (2) He may be insulated positively and treated with an oscillating breeze.

The patient should remove his shoes and stand in the reservoir foot-electrode if the current is interrupted. The foot-electrode is first filled with warm water, and is connected with the prime conductor. The cage is lowered over the patient so that he stands in its center. There is a distance of about 6 inches between the wires that suspend the cage and the patient's head. The sliding-poles are short-circuited, and the machine set in motion. Gradually separate the poles until the patient experiences a comfortable thrill. It is always better for the beginner to first try negative electrification and the positive breeze, as the negative breeze might be too irritating or annoying to a nervous patient.

To give a simple breeze the sliding-poles are widely separated at the beginning, instead of being short-circuited.

PLATE XXI.

Posture in Treatment of Sciatica.

20492

44. The cage is used for its general tonic and sedative effects. Neuroses and diseases characterized by slowness of nutrition afford the best field for its use. It produces the physiological effects on metabolism ascribed to high-frequency high-potential currents. The chief fact to remember about treatment with the cage is that it is either simple negative or positive electrification, with a continued or interrupted breeze applied to the surface of the entire body. It is a diffuse, extended, breeze application, and much less energetic than the local breeze, and as a tonic is surpassed by potential alternation. Few use the cage at present.

MASSAGE-ROLLER APPLICATION.

45. Mode of Operation.—The patient may be insulated negatively or positively, and the electrode and opposite pole are grounded, or the electrode may be connected direct to the active pole. The sliding-poles are brought together and then gradually separated until the required action is produced. This is a very efficient method for causing muscle contraction and at the same time producing lively counter-irritation. Other methods are preferable in most cases.

The muscle-contracting effects, as well as the amount of counter-irritation, are regulated by the distance the sliding-poles are separated from each other, and the speed of the plates, manipulation of electrode, and duration of contact.

The massage-roller electrode may be used with Leyden jar currents. Its satisfactory employment requires skill.

FRANKLINIC INTERRUPTED CURRENTS.

46. Prior to 1880, the static machine served as an electric source in the administration of general electrification, positive or negative, and for the local methods known as breeze, spray, and spark. There was no question of static currents. In 1880, W. J. Morton, M. D., originated and described two distinct forms of static currents, namely:

1. *The Indirect Franklinic Interrupted Current.* — In this form of current the spark-gap is in one circuit (the primary) and the

patient in another circuit (the secondary). The current traversing the patient is derived from the external armature of the Leyden jars. Leyden jars or condensers are absolutely indispensable in the generation of this current. The patient is not insulated. This current is still sometimes called *static induced current.*

2. *The Direct Franklinic Interrupted Current.* —Here the spark-gap and the patient are in the same circuit. These two currents, together with the electrodes used in their application, were originated and described by Doctor Morton in 1880.

The dominating character of spark-gap, or Morton, currents is that they produce energetic contraction of muscle-fiber. In general electrification or in the local methods of breeze or spray there is no reaction of motor nerves or muscles. The variation of potential in these methods is neither sufficiently abrupt nor powerful to produce reactions of motor nerves and muscles. In the spark-gap currents each oscillating discharge between the sliding-poles of the machine produces profound contraction in the group of muscles situated in neighborhood of the electrode.

The general technique of indirect Franklinic interrupted, or static induced, currents may be divided into *bipolar* and *monopolar.* In the bipolar method, the patient is included in a circuit that has its origin in the external armatures of Leyden jars. (Plate XXIII.) In the monopolar method, one external armature of the Leyden jar is grounded and the patient is in connection with the external armature of the other Leyden jar. (Plate XXIV.)

47. Bipolar Method.—Indirect Franklinic interrupted currents are used in the same manner and with the same electrodes as the faradic current. Three sets of Leyden jars come with the static machine, viz., large, small, and medium. The question, which one to use, is a matter of dosage. Naturally the larger jars have the greatest capacity, and will give the strongest current. With a 10-plate 30-inch machine run by a ½-horsepower motor, and a fine-coil apparatus, and both in good condition, the physician may find but little use for his indirect Franklinic interrupted currents in therapeutic applications.

PLATE XXII.

Posture in Treatment of Lumbago.

20492

Plate XXIII represents the technique of applying the indirect Franklinic interrupted currents to the larynx. The smallest-sized Leyden jars are connected with the prime conductors, and an electrode is placed on either side of the larynx. The electrodes are first placed in position; the machine is then set in motion, with the discharge-rods in contact. The discharge-rods are now carefully and slowly separated until the effect required is produced. The electrodes should be thoroughly saturated with a solution of bicarbonate of soda and water. The passage of each spark between the discharge-rods is accompanied by a painless contraction of the muscles in the region covered by the electrodes. The current is alternating. This method of treatment is found very useful in chronic congestion and chronic inflammatory conditions of the larynx.

Plate XXV represents the technique of indirect Franklinic interrupted currents applied to the muscles of the forearm. The small Leyden jars are again used; the palmar surface of the patient's hand makes contact with the sponge placed on the movable stand. This sponge is connected with one Leyden jar; the other Leyden jar is in connection with the electrode held in the hand of the operator. This is a very convenient method of exercising the muscles of the forearm or arm. The interruptions may be made slow or rapid, the current weak or strong, as the physician deems necessary.

Plate XXVI shows the application of indirect Franklinic interrupted currents to the lower extremities by means of the foot-bath electrode. Ordinary rheophores are used, attached to pieces of block tin or annealed copper, shaped as shown in the foot-bath. This method of applying Leyden jar currents is very useful in producing muscular contraction and in stimulating the nutrition of the lower extremities.

Plate XXVII illustrates another application of Leyden jar currents much used in daily practice. One electrode is applied to the epigastrium, and the other to a point opposite on the spinal column. The dosage is regulated as in all other Leyden jar applications.

Plate XXVIII shows connections for Leyden jar currents with foot-bath electrode.

48.   Comparison of Indirect Franklinic Interrupted and Coil-Battery Currents.—For gross nerve and muscle effects, there is little difference between indirect Franklinic interrupted currents and currents administered from a scientifically constructed coil-battery.   With slow interruptions in the indirect Franklinic interrupted current the muscles have time to contract and relax, and they undergo the physiological hypertrophy described by Debedat.   With rapid interruptions and strong discharge the muscles are tetanized, and if the séance is long, exhaustion will result.   The difference in the current coming from small, medium, or large Leyden jars is simply a question of current-strength.   The electricity is the same.   The larger the Leyden jar, the larger its condensing capacity.   Indirect Franklinic interrupted currents are not suited for the treatment of inflammatory conditions, and particularly in inflammatory pelvic troubles.   The indirect Franklinic interrupted current is less steady and more uncertain in its make and break than the current coming from a well-constructed coil-battery.   The physician may easily demonstrate this to his own satisfaction by testing both currents with a telephone receiver.   The current from the well-constructed coil-battery will be found smooth and even in its workings; the current from the Leyden jars will be found unsteady, jerky, irregular, and interspersed here and there with secondary discharges.   It is for this reason that the coil-current is universally employed as a pain-relieving agent in acute inflammatory diseases and particularly in inflammatory affections of the pelvis.   The indirect Franklinic interrupted currents are not suitable in these maladies.   The indirect Franklinic interrupted currents are regulated by the rapidity of the revolutions of the plates and the distance the sliding-poles are separated from each other.   With the speed of the plates regulated, and the distance between the sliding-poles properly adjusted, the largest-sized Leyden jars may be made to produce practically the same effects as the smallest-sized jars.   It will be remembered that practically the same thing has been said about the physiological properties of fine and coarse coils.   Indeed, with the smallest Leyden jars and rapid revolution of the plates, the effects of a current from a long fine-wire coil are very closely

reproduced.   The medium-sized jars with rapid revolutions of the plates correspond to the current from the coarse-wire coil rapidly interrupted.   The largest-sized jars correspond to the coarse-wire coil, and may be used for the same purpose.

49.   It will thus be seen that currents from Leyden jars of different sizes are parallel in their effects to the currents from a scientifically constructed coil-battery.   The main fact to be remembered is that indirect Franklinic interrupted currents are not suited to acute inflammatory conditions, and that they are completely superseded by coil-currents in the treatment of painful pelvic maladies.

50.   Another point to consider is this: the Leyden jars are charged by the static machine.   Now, about all that can be accomplished by the indirect Franklinic interrupted currents can be accomplished in a much more pleasing and agreeable manner by the static machine without condensers.   If one possesses the static machine, one rarely needs the Leyden jars for therapeutic purposes.   In X-ray work, however, the condensers often become a necessity.   The whole range of faradic therapeutics may be covered by indirect Franklinic interrupted currents, rheophores and electrodes being the same.   No rheostat, or current-controller, is absolutely required, as the speed of the machine and the distance separating the poles are the direct and indispensable means of regulating the current-strength.   To use a rheostat, therefore, makes an additional adjustment necessary, and adds no actual value to the treatment; but one can be employed if the operator so desires   The one used is simply an enlargement of the galvanic water-rheostat long familiar to physicians

51.   Monopolar Method.—There are two currents to be considered in this technique.   When the patient is in communication with the external armature of the Leyden jar connected with the positive pole of the static machine, the current may be called negative; and when he is in communication with the external armature of the Leyden jar connected with the negative pole, the current may be called positive.   These are high-potential high-frequency currents analogous to, but not indentical with, the Tesla-d'Arsonval currents.

In the monopolar method of applying indirect Franklinic interrupted currents the armature not in use is always grounded. When the electrode of either of these currents is approached to a patient non-insulated, a beautiful spray is produced; but the spray from the positive current is much more effective and important than the spray from the negative current. The general application of these currents to the organism produces the same order of phenomena as those produced by the Tesla-d'Arsonval currents (see Art. **83**).

The spray and spark administered by the same technique produce the same phenomena as the spray and spark from the Tesla-d'Arsonval currents. The sparks from the negative current are, however, much more painful than those from the positive current. If the armature of one Leyden jar is connected with an olive-tipped electrode and this electrode is placed on a muscle or nerve, very active and extensive muscular contractions are produced.

POTENTIAL ALTERNATION.

52. Essential Features.—By **potential-alternation treatment** the patient is submitted to the energetic influence of an interrupted oscillating current. Plate VI illustrates the technique of potential alternation. The platform is prepared the same as for simple positive electrification, and the negative pole d is grounded. The essential feature of the method lies in the interruption of the current between the prime conductor e' and the patient. The head-electrode a is kept at a distance of about 2 feet and is grounded with the negative pole d. In order to prevent the passage of sparks through the nails in the patient's shoes, place a sufficient number of thick newspapers between the brass-plate electrode and the soles of the shoes.

53. Interrupting the Current.—To interrupt the current, fix the large brass-ball electrode in the movable stand f, and place the ball h of the electrode in contact with the small ball g of the connecting-rod b attached to the sliding-pole d'. The movable brass-ball electrode is now grounded. Different groundings in this form of treatment are advantageous. If the

PLATE XXIII.

Indirect Franklinic Interrupted Current—Bipolar Method.

negative pole is grounded to the water-pipe, ground the electrode to the chandelier or gas-bracket. Set the machine in motion, and gradually separate the balls of the electrode and the conducting-rod until the patient experiences a comfortable thrill. This will usually occur at a sparking-gap of 4 or 5 inches, but the author of the method often demonstrates a 10-inch spark. The hair is caused to vibrate vigorously. Both feet should be kept in contact with the metal foot-plate during the entire séance, the usual length of which is 15 minutes. The author of this form of treatment demonstrates by it powerful tonic sedative effects, and strongly recommends its use in cases of exhaustion, mental or physical, no matter how produced. The effect of the interruption is to energize current action and subject the patient to the influences of an oscillating current.

Potential alternation, applied as described, is interrupted general electrification. By approaching a grounded electrode to the prime conductor in use, the potential of the patient is reduced to zero. He is again immediately charged by the output from the machine. His potential is therefore made to alternate between zero and the potential of the current employed.

Plates XXIX and XXX illustrate potential alternation locally applied. In Plate XXIX, a chain connected to the discharge-rod is wound around the muscles of the arm. A grounded electrode interrupts the current on the prime conductor in use. Each spark thus caused produces vigorous, extended, painless contraction of the muscles of the arm. According to S. H. Monell, M. D., there is no method superior to this for exercising the muscles of the arm. The muscles act vigorously beneath the skin, and the skin itself takes on a tanned color, as if exposed to sunlight. The sparks are applied to the prime conductor, and not to the patient, as in the usual spark-treatment.

Plate XXX illustrates a technique somewhat different, yet it is potential alternation locally applied. The glass jar is filled three-quarters with water, and becomes the active electrode. On applying sparks to the prime conductor, the muscles of the hand, forearm, or arm will be painlessly exercised, depending on the depth to which the hand is placed in the water.

Potential alternation, whether applied as interrupted general electrification, or locally by means of the chain- or bath-electrodes, as illustrated in Plates XXIX and XXX, constitutes a very important form of static treatment, and one that renders valuable service when tonic sedative effects are required.

THE WAVE-CURRENT.

54. This current "was first so termed because its circuit, to be completed, produced Hertzian waves emanating from the patient's person." The wave-current was first published in the Bulletin Officiel de la Société Française d'Eléctrothérapie, of January, 1899, and later in the Electrical Engineer of March 4. Plate XXXI illustrates the technique of applying the wave-current to the ankle-joint with a metallic braid as an elec trode, while Plate XXXII illustrates the same current applied to the spinal column by means of a sheet-lead electrode 20 inches long and 1½ inches wide, and Plate XXXIII illustrates the wave-current applied to the soles of the feet by means of the brass pláte electrode. The electrodes are attached to the positive pole, and the negative pole is grounded. Before the machine is set in motion the discharge-rods are placed in contact. The plates are then started revolving and the sliding-poles gradually separated, until the desired effect is produced. The sliding-poles should be separated very slowly.

A 1-inch spark-gap may at first annoy the patient, but the sedative effect of this spark-gap acting within the tissues will, in a few minutes, permit an increase in its length until, finally, a current-strength represented by a spark-gap of 8 or 10 inches may be attained. The position of the patient on the platform, whether sitting, standing, or reclining, will depend on his physical condition and the details involved in the application of the electrodes.

Ordinary rheophores used in galvanic and faradic applications are used to connect the electrode with the active pole of the machine. One end of the rheophore should be provided with a metallic hook for attachment to the active pole of the machine, while to the other end of the rheophore is attached a Herdman

universal connector for attachment to the block tin, sheet lead, or metal braid of which the electrode is constructed.

The electrode must be placed in close contact with the surface treated in order to avoid disagreeable sensations. To secure accurate contact with the contours of the joints, tinsel braid will be found the most serviceable. Block tin, gages 22 and 33, and sheet lead are usually employed for electrodes applied to other surfaces of the body. These latter should be held in position by the patient's hand or by bandages. When the large electrode is applied to the spinal column, a high-backed chair with pillows appropriately disposed will secure good contact.

The size of the electrode in wave-current applications is determined by the same considerations as in all other electrical applications, namely, current-density and the pathological condition under treatment. When applied to the muscles of the thigh, leg, or trunk of an adult, an electrode should not exceed 24 square inches in size for a spark-gap of 4 or 5 inches.

With a feeble current output to secure the same current-density, the size of the electrode must be considerably diminished. If the physician will administer to his own person a few applications of the wave-current with electrodes of different sizes and with different current-densities, his knowledge of the subject-matter in question will be materially increased in practical value. Special electrodes for treating mucous surfaces and the open cavities of the body can be obtained from manufacturers. The possible maximum spark-length at the time of administration will depend on (1) the capacity of the machine, which will depend on its condition and the diameter of the revolving plates, (2) the condition of the atmosphere, (3) the speed of the machine, (4) the character of the insulation, (5) the proximity of surrounding objects, (6) the physical characteristics and clothing of the patient.

55. Physiological Effects.—The physiological effects of wave-current administration may be considered under two headings, namely, constitutional effects and local effects. As the patient is always insulated in these applications, his organism is submitted to the physiological influence of general

electrification with which the student is already familiar.   The
interruption increases the energy of the current and corre-
spondingly the physiological actions of simple continuous elec-
trification.   We shall therefore describe here only those actions
that take place beneath and around the electrode applied to the
patient's body.   These actions may be stated in three words,
namely, anticongestive, analgesic, and nutritive.

In the tissues immediately beneath the electrode, marked
vibratory effects are produced.   The hairs on the head and
surface of the patient's body respond to the rapid oscillations
of the current.   The electrode is always moist when removed,
demonstrating action on the vasomotor nerves producing
increased activity of the sudoriparous glands.

Muscular contraction is most marked when the electrode is
placed over a motor point, as is the case in the application of
any other electric modality.

The following clinical effects have been pointed out by
William Benham Snow, M. D.   (1) Local congestion is
relieved, often with marked diminution of swelling and pain;
(2) relief of local pain or tenderness from many causes, is
marked; (3) relaxation of acute muscular spasm not of central
origin; (4) increased local metabolism and repair, if reparative
conditions are sluggish.

The chief physiological and clinical effects of wave-currents
locally applied are relief of hyperemia, congestion, and pain,
and an increased activity in metabolic processes.

The therapeutic indications of the wave-current are based on
its clinical effects and physiological actions, and these cover a
wide range of application in every department of medicine and
surgery.

PHYSIOLOGY.

56. Static Electricity a Regulator of Functions.
The description of platform methods involved a brief descrip-
tion of the physiological action and therapeutic application of
static electricity.   Static electricity employed in the form of
breeze, spray, or spark, or administered with rheophores and
electrodes, with or without Leyden jars, is preeminently a

regulator of functions. By chemical analysis it has been demonstrated that it increases metabolism and creates a demand for oxygen within the tissues. This increased metabolism, this created demand for an increased amount of oxygen, is brought about by improving the process of oxidation. In conditions in which the temperature is subnormal, static treatment regulates the heat-producing functions and restores temperature to its normal degree. Irregularities in respiration are rapidly corrected and the normal rhythm restored. Exceptions to this are found in icterus and other hepatic diseases associated with melancholia and subnormal temperatures.

57. Action of Static Electricity.—If the pulse for any reason is too slow, static treatment will increase it to the normal; if it is too rapid, it will tend to restore it to its normal rate. An individual with all his organs healthy and their functions normal in themselves and working in harmony will be but slightly affected by a simple static charge. The action of static electricity depends, in a great measure, on its therapeutic indications. One would not give stomach-tonics to an individual whose digestive apparatus was functionally normal, nor morphin to a man of perfect health without emotion and without pain. Certainly, if the stomach-tonics or morphin are given in these conditions, they will not produce the gratifying response that attends them when exhibited according to their well-known indications. The same is true in the case of static electricity. Pain must exist before it can be removed. Irregularities in cardiac action, either intermittent, too rapid, or too slow; too weak or too strong; irregularities in respiratory rhythm, nervous or congestive; too little or too much secretion or excretion; too high or too low temperature: these are all conditions that must exist before they can be controlled. On the typically healthy individual, static electrification has little or no effect. For the individual with this or that functional derangement, one or more, static electricity must be conceded to be one of the most powerful therapeutic agents at the physician's diposal. It cannot replace destroyed tissues, but it can often relieve the pain that they produce.

The pain of incurable spinal diseases is often kept completely under control by regular static treatment; the course of the disease is modified and the condition of the patient is rendered comfortable. In cases of paralysis of a curable nature it is the best remedy both in symptomatic treatment and in respect to permanent cure when the galvanic current is not required.

58. Calming Influence of Static Electricity.—One of the most valuable and most frequently utilized qualities of static electricity is its power to calm an irritated nervous system and induce a return to normal sleep. Coincident with this comes increased appetite, restored digestion, and renewed strength and vigor. The well-known dangers of drug remedies such as morphin, chloral, bromid of potash, paraldehyde, sulfonal, trional, in the treatment of the various forms of insomnia, ought to give an agent like static electricity, at once effective and without danger, a popularity much more extended than it now enjoys. Reflex pains are but too often the cause of nervous irritability and consequent insomnia. Static electricity administered in the form of friction-sparks is among the most effective agents known to therapeutics to relieve and cure these pains. Painful sensations probably travel along the paths of least resistance, and in their way out create the most direct route for the inward transmission of counter-electrical impressions that serve to annul the pains.

59. Report on Standard Electrostatic or Influence Machines.—A summary of modern opinion on the action of static currents may be obtained from the following abstract taken from the report of the committee on "Standard Electrostatic or Influence Machines," presented to the convention of the American Electrotherapeutic Association, and published in the "Times and Register," December 29, 1894:

The physiological effects of static electricity are pretty much all that are produced by electricity. It sets free the potential energy of the cells of the human organism. That is, it excites the cell in such a way that its inherent energy is liberated. Its wide range of effects vary with and depend somewhat on the manner in which it is applied. It causes

PLATE XXIV.

Indirect Franklinic Interrupted Current—Monopolar Method.

.

contraction of protoplasm, both animal and vegetable.   It excites nerve-fibers, nerve-cells, and nerve-centers.   All of these are excited to functional action and caused to produce their separate effects—motor, sensory, special sense, secretory, sympathetic, vasomotor, etc.   It has a mechanical action.   It disturbs the molecular arrangement of tissues, and causes a new structural arrangement resulting in modifications of nutrition.   Its general effects are of great range and of astonishing importance.   They may be briefly stated as follows:

It promotes nutrition of every part it excites; produces marked local and general circulatory effects, and stimulates the vasomotor nervous system.   It promotes metabolism and tissue metamorphosis; creates a feeling of refreshment to the system; causes the reabsorption of exudative material of a chronic nature, and has a revulsive action on the skin.   It is both a cutaneous sedative and a counter-irritant, and makes a powerful peripheral impression of great value in neurasthenia.   The subject of reflex pains is of constant interest to a physician. Pains are often referred by patients to points distant from their origin.   Possibly a pain travels along the path of least possible resistance, and in its outward path prepares the way for the return of a curative influence along the same path.   No matter how far from the local irritation a reflected pain may manifest itself, spark the sore place and its impression will track the pain to its seat and drive it out.

We cannot always cure altered structure, but we can correct functional pains, and often relieve organic pains by setting up powerful ingoing impressions and displacing the pains.

60.   The list of diseases in which static electricity can be beneficially employed is a very long one.   In cases of malnutrition it is an excellent tonic.   Its great fields are functional and nervous diseases.

Neurasthenia, hysteria, neuralgia, nervous headaches, etc. are rapidly controlled by it.   In diseases of the spinal cord it affords relief from various forms of pain, even when lesions are advanced beyond cure.   It is invaluable in rheumatism, chronic synovitis, and chorea.   It is one of the best general tonics we

possess, and as such is very easy and agreeable of application, and can be used in a great variety of cases. In the treatment of paralysis of curable forms, it is one of the most successful agents we have. During a static séance, to obtain these striking results, the patient must be placed in as favorable a condition as possible. Constrained attitudes, cold drafts of air, annoying or disturbing conditions of any kind, must be avoided.

It was long taught, and is a very prevalent mistake today, that static electricity is a mere "surface" charge, and that its therapeutic effects must necessarily be limited to surface action. Let us see what the truth is.

61. Chief Physical Property of Static Electricity. The chief physical quality of static electricity is its enormous voltage. The quality that any electric current possesses of penetrating bodies or overcoming resistance is due to its voltage. It would therefore seem strange that the faradic and galvanic currents, with their comparatively low voltage, penetrate tissue, and that static electricity, with its enormous voltage, was limited to the exterior. The human body is a conductor of electricity; the air is an insulator. Static electricity, in the physical condition of a charge, has sufficient penetrating power to overcome the resistance of 4 or more inches of intervening air, through which it forces its way in the form of a spray or spark. Nothing of this kind can be accomplished by the medical battery, galvanic or faradic. Another striking evidence of the penetrating power of static electricity, due to its enormous voltage, is seen in the phenomenon of an illuminated Crookes tube. No medical faradic battery yet constructed has sufficient voltage to overcome the resistance of the vacuum in a Crookes tube. Surface action would not contract muscles as does the static current, and in many ways the surface idea has long been exploded.

62. Its Kinetic Nature.—In these different evidences of penetrating power, static electricity is flowing in a kinetic form. It is not a mere charge at rest. When using the interrupted current or Leyden jar current, there is no doubt that the electric current passes through the body from one

PLATE XXV.

Indirect Franklinic Interrupted Current Applied to Muscles of Forearm.

20492

electrode to the other.   When, however, the patient is insulated positively, and the negative prime conductor is grounded, the physical conditions are different, but the current obeys the same electric laws.   No one can sit a single moment upon a static platform and have any question about the penetrating properties of static electricity when the facts are demonstrated to his tissues by the point or ball electrodes.   Old writers did not test the matter this way, but set up unproved theories which others kept repeating.

63.   Molecular Disturbance Produced.—The static spark produces molecular disturbance in the tissues to which it is applied.   New molecular combinations are thus formed, and long-standing exudates and infiltrations are so changed that they can be taken up by the lymphatics and blood-vessels, or eliminated by the different emunctories.   The action of the long, clean-cut, percussive spark is essentially mechanical or perturbatory, dissociating the parts of which diseased structures are composed, permitting of new arrangements and healthier combinations.   Indurated and infiltrated, thickened and edematous tissues under percussive-spark treatment are often soon absorbed and the affected parts again take on a healthy aspect.   The more indications there are for percussive sparks, the more tolerable will be their application and the more beneficial their results.

64.   Nature of the Frictional Spark.—The frictional spark, on account of its efficiency as a therapeutic agent and the facility of its application, requires special notice.   It is essentially a rubefacient and counter-irritant, and can be made to vesicate in a few minutes, but this is never done in good practice.   As a rule, in medicine, counter-irritation is produced by one of two methods; viz., either by sinapism or by a blister.   Other means may be employed, but these two are honored by tradition and are used daily in routine practice; they are, how-ever, both surpassed by static frictions.

65.   Counter-Irritation.—No special dogma is needed today to explain the *methodus medendi* of counter-irritation. Claude Bernard and Bichat gave the first glimmerings of the

true explanation of the well-known curative powers of counter-irritation in beginning the foundation of physiological thera-peutics.   Duchenne located, in the anterior cornua of the spinal cord, the real cause of a great deal of myopathic paralysis. Diseased peripheral nerves were next proved clinically and experimentally to produce central spinal lesions.   Through work done in the physiological laboratory, reflexes and reflex actions became thoroughly familiar to all physicians.   The action of the vasodilator and the vasoconstrictor nerves and their influences on the circulation, local and general, has become common knowledge in medicine, and the physician no longer looks to this or that master for a specious theory to explain the *raison d'être* of counter-irritation.   Applied to a large surface of the body for an appropriate length of time, counter-irritation produces a redness of the superficies acted on, and this redness extends for some distance beyond the area irritated; the cardiac action is accelerated, the tempera-ture of the body is elevated, and the irritability of the cerebro-spinal system is increased.   If this irritation is too violent in its energy, or too long continued, it is capable of working serious mischief.   The trophic influence of counter-irritation is made very manifest and convincing in the study of burns or injuries affecting large areas of skin tissue.   It is a well-known clinical fact that the depth of a burn or injury does not affect the trophic condition as much as the extent of surface involved. Thus, the arm may be completely charred to the elbow, and there will follow no pneumonia, no atrophic ulceration of the duodenum.   The prognosis of burns depends more on their extent than on their depth; more on the number of nerve-filaments involved than on the intensity of the disease or trauma of any given nerve-fibril.   The trophic influence of counter-irritation and its *modus operandi* can receive no more striking illustration than is given in the ulcerated duodenum following extensive yet superficial burns of cutaneous surface.

66.   To every action there is an exact and equal reaction. This is a physical law and has no exceptions.   In the case of the burn, the spinal trophic centers were paralyzed by the
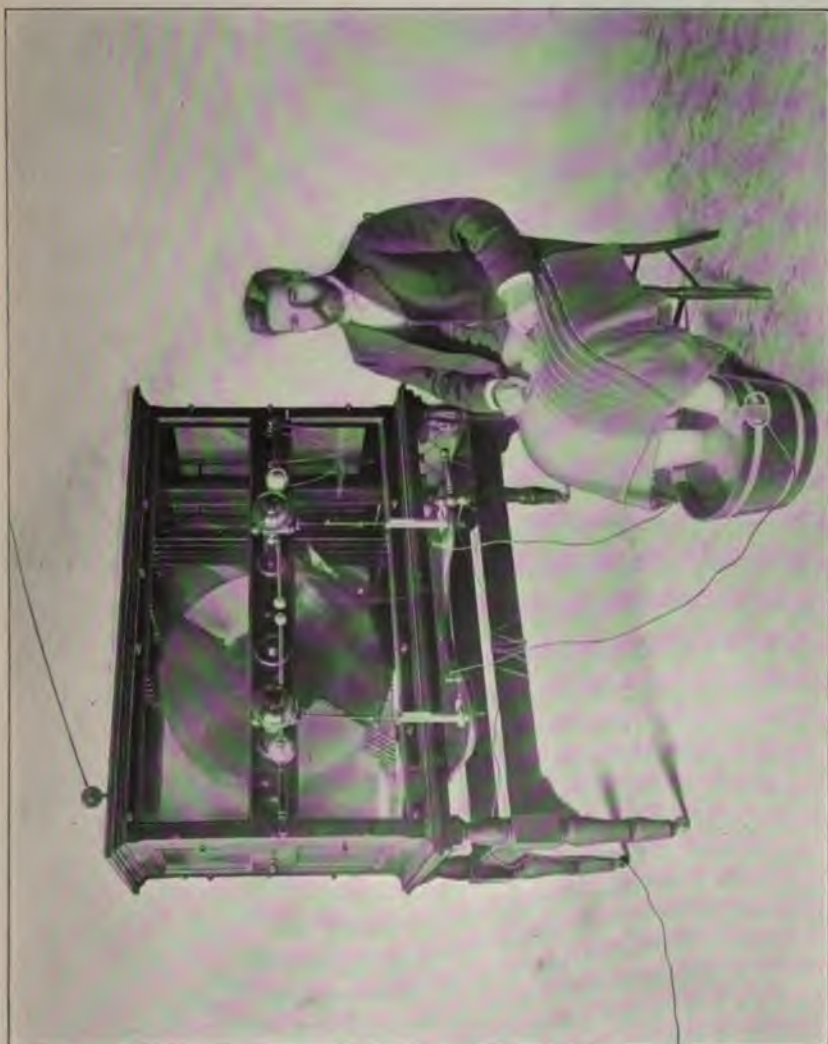
PLATE XXVI.

Indirect Franklinic Interrupted Current—Foot-Bath Electrode.

20492

counter-irritation produced, and the nerves coming from those centers no longer performed their functions, while the parts to which they were distributed necessarily underwent atrophic changes. The intensity of the counter-irritation and the length of time it is continued controls *in toto* its therapeutic results. Over static electricity, as a means of producing counter-irritation, the operator has absolute control, both as to intensity and duration of application. Thus, with proper care and skill, he can in a few seconds produce a mild diffuse redness very agreeable to the patient; or the same area operated on, by changing the manipulations and conditions, can be subjected to any or every gradation of counter-irritation that can be produced by the skilful operator, pathological indications alone controlling his work.

67. Modification of Functions.—The amount of blood imprisoned in the artificially congested area by a sinapism, or the amount of serum withdrawn from the general circulation by a blister, counts but little in the sum total of the beneficial and curative effects of these two agents. Much more consoling to the physician are the results demonstrated by Doctor Hodges. In a series of careful experiments this investigator proves that impressions made on the peripheral endings of the sensory nerves are transported to the central ganglia, and are capable of producing there organic changes. This seems to be the pivotal point upon which must ever rest the physiological therapeutics of counter-irritation. The point which is of interest to the physician and which he should always remember is that central ganglia may be modified in their functions and changed in their organic structure by impressions made on the superficies of the body.

68. The results demonstrated by Doctor Hodges make it easily understood how friction and sparks operate in arresting the march of degenerative cord diseases. They make clear the *methodus medendi* of electricity, in all varieties of reflex pains, no matter what may be the direct cause of irritation. The reddened skin and the wheal-like and papular eruption are but superficial manifestations of the effects produced by electric

energy. Beyond the skin, and within the central ganglia, spinal or cerebral, enduring changes are apparently established, which determine the real value of static electricity in daily practice. No amount of discussion on electrotechnical theories can alter the value of this now demonstrated fact, and the physician administering static electricity can feel himself secure on a physiological and rational therapeutic basis. It is the most important demonstration made since static electricity was first used for therapeutic purposes.

DOSAGE.

69. Regulation of Dosage.—With the static machine in full motion and a patient being treated, the physician habituated to the use of galvanism and faradism at once observes the absence of rheostats and meters. Without these means, how is the dosage of static electricity regulated? It depends much on the technique of the given application.

70. The static dose may be increased by the following means:

1. The electrical output of the static machine varies with the rapidity of the revolutions of its plates. The faster the plates revolve, the greater will be the electrical output. The rapidity of the revolution of the plates is regulated through the rheostat in the motor circuit, when a motor is used to run the machine. To regulate the motion of an 8-plate 30-inch machine, allowing all conceivable gradations from the slowest movements to racing motions, 175 ohms will be sufficient. If turned by hand, the rate can be controlled still more easily.

2. The dose is further regulated by the means employed to conduct the electricity from the prime conductor to the patient. The least energetic manner of conducting the electricity to the patient on the insulated platform is by placing the platform-rod on a part of the platform as far removed as possible from the patient. In this way much of the current is wasted in traversing the wooden surface before it reaches the patient. The waste of current produced in this manner can be easily verified by requesting the individual on the platform to

PLATE XXVII.

Indirect Franklinic Interrupted Current.

approach his finger to the prime conductor with which the platform is connected.   If there is no current waste, no spark will pass between the patient's finger and the prime conductor. If a spark passes, it demonstrates a difference of potential and a consequent waste of current.

71.   Direct Metallic Conduction.—The best means of conveying an electric charge from the prime conductor to the insulated patient is by means of direct metallic conduction. This may be done in one of two ways; viz., the patient holds the platform-rod attached to the prime conductor in both his hands, or the patient's feet may rest on a metallic electrode, which is attached by means of a chain to the connecting-rod resting somewhere on the platform.   Either of these two methods constitutes direct metallic conduction, and is the surest way of giving to the patient the entire electric output of the machine.

Without direct metallic conduction, the dosage may be slightly increased or diminished by approaching or withdrawing the platform-rod to or from the patient.   Office furniture placed too near the platform will attract the current and thus diminish the charge.   In the hot, damp days of summer, the plates and interior mechanism of the static machine should be kept thoroughly dry.   This is best done by frequently rebaking the calcium chlorid.   The atmosphere of the office may be dried of moisture by lighting a few gas-jets or by closing the windows and keeping a fire burning for an hour or two.

72.   How to Increase Current Output.—Only those skilled in the technique of static electricity should employ Leyden jars to increase the current.   An accident might easily happen with the Leyden jars in unskilled hands, which would detract much from the reputation of the operator.   The breeze, spray, and frictional spark may be increased in energy by interrupting the current between the prime conductor and the patient.   This is best done by the patient holding one end of the platform-rod in his hand and resting the other end on the case of the machine, so that the rod is about ½ or ¾ inch from the sliding-pole. This will cause a spark to pass between the platform-rod and

the sliding-pole. This is the most efficient and at the same time the simplest method of increasing the strength of local and general static applications.

73. Mild Application of Spray.—The mildest breeze or spray application is made in the following manner: The patient is insulated negatively or positively, and the operator simply holds the metallic part of the electrode in his hands without any connection with the earth, and bringing it to the necessary distance from the patient. In this way a very mild spark may be administered, but each spark will cause a contraction in the operator's wrist. The strength or energy of the breeze, spray, or spark may be diminished by any of the following means:

1. The operator may leak off some of the charge through his foot, placed for the moment on the platform.

2. The machine may be made to run more slowly.

3. The metallic connecting-rod may be taken from the hands of the patient and placed upon the platform.

4. The farther the rod is placed from the patient's feet the less energetic will be the spark, spray, or breeze.

In continuous-current administration, direct metallic connection with either hands or feet does not in the least annoy the patient, and the maximum current is thereby obtained.

74. Essentials of Static Dosage.—The essentials of static dosage may be regulated to a nicety by attention to the following details:

1. The rapidity of the revolution of the plates, whether slow, medium, or fast, must be carefully noted.

2. The condition of the atmosphere, both within and without the static case, is a matter of importance.

3. The calcium chlorid should be comparatively dry.

4. The means employed to convey the electric charge from the prime conductor to the patient should be considered.

5. If the conduction is indirect, regulate the distance between the patient's feet and the conducting-rod.

6. Keep surrounding objects at such a distance that they will not attract the current.
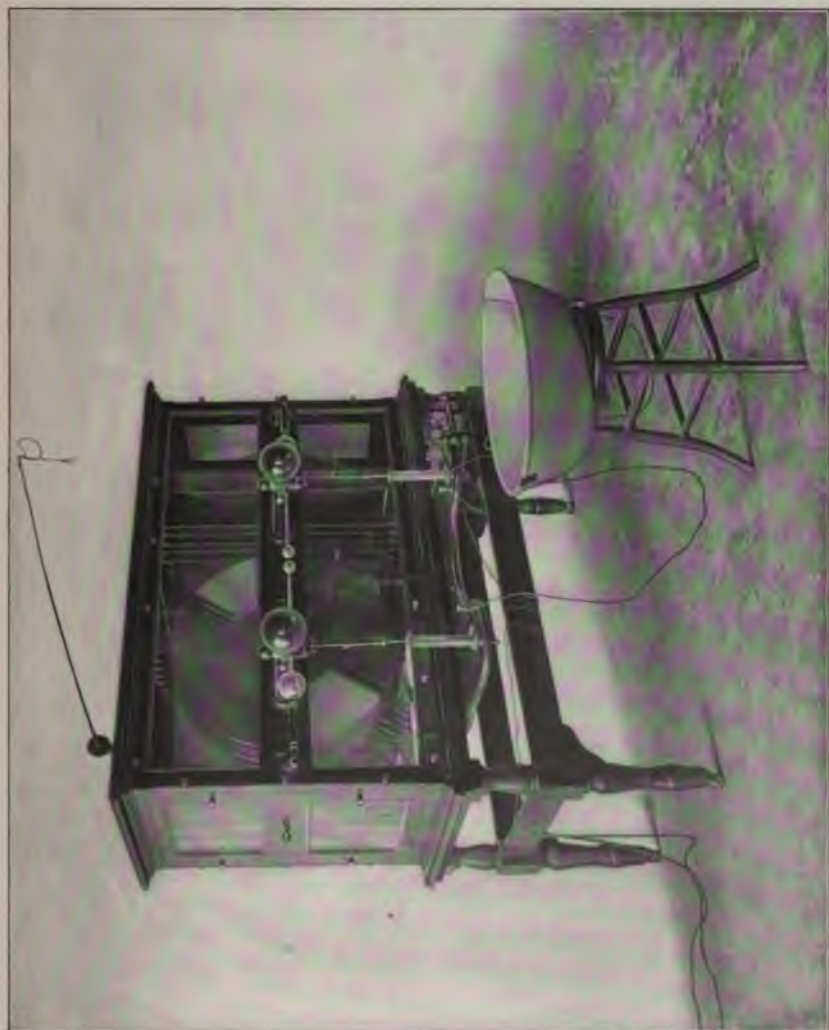
PLATE XXVIII.

Indirect Franklinic Interrupted Current—Foot-Bath Electrode.

20492

7. Remember that accumulation of current is a *sine qua non* in successful static therapeutics, and that every detail that fosters it should receive studious attention.

APPLICATION OF STATIC ELECTRICITY IN DISEASE.

75. Limitations.—To advocate the use of static electricity in all diseases brings one within the realm of charlatanism. To write that static electricity may be beneficially and appropriately employed in some stages of every disease or injury puts the question on a strictly clinical and demonstrable basis, and the assertion can be supported by anatomico-physiological researches. The great additional factor, the advantage afforded in its ·general use, allowance being made for its wonderful therapeutic properties, is that all treatment may be given without the patient removing any of his or her clothing. Every practitioner that has had any experience in electrotherapeutics knows the time consumed in, and the embarrassment connected with, every general galvanic or faradic application. When the patient is in possession of all his faculties, mental as well as physical, disrobing may be conveniently resorted to, but when mental and physical disabilities are present, the act of disrobing, besides the time consumed, well-nigh counterbalances the value of general faradization. Static electricity, therefore, is the most suitable current for general office practice and general treatment, but owing to the height and size of the machine it is not portable, and this confines it to the physician's office; the patient must always be able to go to the machine—the machine, at least at present, cannot go to the patient. This fact excludes a large class of diseases from the benefit of static treatment.

76. Acute infectious fevers, contagious diseases, and, in general, all maladies requiring rest and recumbency, do not, however, come within the domain of static therapeutics. Its great field of use is found in functional nutritional diseases, in controlling the nervous, the circulatory, the respiratory, the muscular, the secretory, and the excretory systems, and as a regulator of function and a distributor of harmony. These

functional nutritional derangements may be either acute or chronic; they are both amenable to static treatment. Each operator will find it necessary to study the mechanism and adjustment of the machine he purchases before he can expect to obtain from it its best therapeutic work. Before a new machine settles down to steady and efficient work, it must be carefully adjusted and regulated. The physician expecting efficient work from his static machine must give it the same scrupulous care that he would give to any other machine or being from which he expected certain work. Indeed, static electricity and the mechanism that excites it ought to be considered separately.

77. Practical Uses of Static Electricity.—What, then, are the practical every-day uses of static electricity?

1. It gives tone and nutrition to sluggish, wasted, or atrophied muscles.

2. It regulates nerve-action, either as a sedative or as a stimulant.

3. Reflex pains, no matter how produced, are relieved or cured.

4. As a sedative and stimulating tonic it may be beneficially employed in many debilitated conditions, such as malaria, nervous exhaustion, prebacillary stage of tuberculosis, and in cases of simple anemia. After all major operations, and in convalescence from all diseases, static electricity is an invaluable therapeutic agent. In a physician's office it will illuminate a Crookes tube. In this way, fractures, dislocations, and various diseases of the bony framework may be continuously and scientifically studied. An osseous tumor, in its evolution, may be thus watched from week to week, and its increase of growth noted. It will also charge the condensers necessary in the production of Tesla-d'Arsonval currents.

5. Muscular pains of rheumatic or traumatic origin, no matter where situated, are readily treated and quickly relieved. Thus, sparking or friction will speedily relieve recent lumbago or any other form of muscular rheumatism.

6. *The different local methods —spark, spray, or breeze—have*

PLATE XXIX.

Contracting Muscles of Arm by Interrupting Current at Terminal of Discharge-Rod.

20492

different local action, according to the conditions present and the manipulations of the physician.

78. High-Potential Currents. — Beyond these local effects the ever-present and valuable effects of high-potential high-frequency currents must not be forgotten. Metabolism of tissue is increased by every static treatment from 20 to 40 per cent. The amount of uric acid excreted is diminished, and the amount of carbonic acid, water, and urea increased. This amounts to saying that the demand created in the tissues for oxygen increases the oxidizing processes of the body from 20 to 40 per cent. The perturbatory action of the thick percussive spark, the counter-irritant and rubefacient effects of the short friction-spark, have been before described. Theoretically, the indications for the uses of static electricity are as wide as the range of disease itself; but, *in practice, the disease, the patient, and the static machine must all be considered,* and it is only when all the indications from these are in harmony, and able to cooperate to attain a given end, that the physiological and therapeutic properties of static electricity are exhibited at their best. The short road to learn how to get the best results is to carefully study the technique illustrated and described in this Section. The method of self-treatment is particularly recommended to the student.

79. The use of static electricity as the best agent to illuminate a Crookes tube, the facility that static electricity offers for general electrification without disrobing and without any discomfort whatever, must give to the static machine in the very near future a much wider popularity than it now commands, and it only lacks use now where it is not known.

_____

DURATION AND FREQUENCY OF TREATMENT.

80. The average length of treatment in methods producing general electrification is from 10 to 15 minutes. The duration of any form of local application depends on getting the effects desired. Stimulating and counter-irritant applications are usually very short, and these effects are often obtained in from ½ minute to 2 minutes. Tonic applications are of medium

length, while sedation must nearly always require a longer
treatment. The length of time also varies with different cases,
so that the sole rule of practice is to get the desired effect before
closing the séance.

In acute or painful diseases a daily treatment is advisable
until improvement permits a longer interval. In most chronic
diseases the rule is three treatments per week.

81. Action and Effect of Methods.— In the foregoing
pages are described the standard methods of employing static
electricity. In therapeutic administration these methods must
be directed to produce effects that will represent indicated thera-
peutic actions. For instance, a negative static breeze may not
treat any disease *per se*, but counter-irritation produced by
means of the negative static breeze may be as effective treat-
ment as any other form of counter-irritation. The student
therefore should study the methods described in this Section
with a view to mastering the effects that each method can
be caused to produce by proper variations in technique, for
*Technique and Physiology of Static and Other High-Frequency
Currents* is written from the standpoint of the action and effect
of methods.

USEFUL HINTS.*

82. Don't neglect proper care of the machine.

Don't expose it to damp drafts.

Don't operate it in too small a room.

Don't place the platform and patient too near the machine
or gas-fixture.

Don't place objects of furniture so near that they will attract
the current from your patient.

Don't stand so near the patient yourself that you will do
the same.

Don't allow an electrified patient to touch objects or shake
hands with a visitor.

Don't pass so near your electrified patient while directing

---

*Quoted with the author's permission from "Manual of Static Elec-
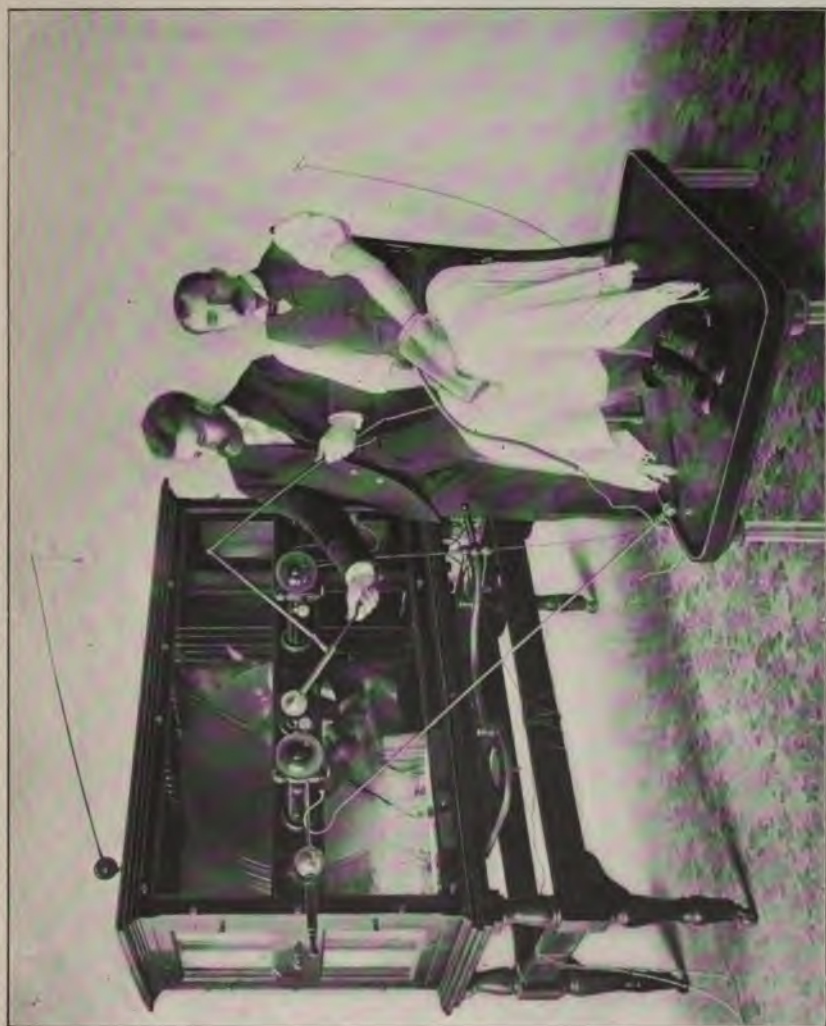tricity in X-Ray and Therapeutic Uses," by S. H. Monell, M. D.

PLATE XXX.

Direct Franklinic Interrupted Current—Hand-Bath Electrode.

20492

treatment that you will draw an unexpected spark and startle your patient unnecessarily.

Don't incautiously handle a charged Leyden jar.

Don't seat a patient for treatment on a chair that contains ornamental brass-headed nails in its upholstery.

Don't fail to remember corset-steels, wires, hairpins, buckles, metallic trimmings, etc., in directing local application in neurasthenia.

Don't forget that the thickness, dryness, and quantity of a patient's hair will affect the intensity of all applications about the head.

Don't forget that the fit, material, texture, and thickness of garments directly influence some forms of static applications, which must be modified accordingly.

Don't forget that static sparks are not always popular, and remember that you have a patient to treat as well as a pathological condition.

Don't forget to ground the electrode.

Don't start the induced current into action with the sliding-poles wide apart.

Don't fail to see that the machine is charged and in working order before you call your patient for treatment.

Don't forget to ground the indifferent pole.

HIGH-FREQUENCY CURRENTS.

83. Every installation for the generation of **high-frequency currents** comprises a transformer, each of whose secondary poles is connected both with an air-gap and the internal armature of a Leyden jar, while the external armature is in connection with a solenoid composed of a few turns of thick copper wire.

The term *high-frequency* is employed to designate alternating currents, the number of whose frequency can attain several millions per second. A rapidly interrupted current from the physician's induction-coil is often called a high-frequency current. The sinusoidal current is also termed a high-frequency current. The discharge from the terminals of a static

machine are spoken of as high-frequency discharges. These
are all high-frequency currents, but that form of current which
concerns us now can be produced only by the discharge of a
condenser through an inductorium composed of a few turns of
thick copper wire. The high-frequency currents in question
are known as the *Tesla-d'Arsonval currents*. It is now well
known that these currents were first investigated, and at about
the same time, 1889-93, by Nicola Tesla and d'Arsonval.
Each worked independent of the other. Tesla's investigations
were purely technical, while those of d'Arsonval were instituted
to determine the physiological effects of high-frequency currents
on animals and man. Before describing the physiological
effects and the therapeutic indications of high-frequency cur-
rents we desire, in order to make the subject-matter clearer, to
impress on the mind of the student that electricity is not a
simple unique therapeutic agent.

It is a proteiform physical agent, and each of its forms has
physiological and therapeutic properties peculiar to it. This
would render the physiological effects of electric currents com-
plex, and often contradictory and difficult to comprehend did not
the physical form of the electric wave that traverses the tissues
afford an easy solution of the phenomena. The physical form
of the electric wave produced by the physician's induction-coil
differs from that produced by a sinusoidal apparatus, and to this
difference in the physical form of the waves is due the difference
in physiological effects produced by them. It is for this reason
that we recommend the student to carefully study the physical
characteristics of high-frequency currents, as described in *Electro-
statics and High-Frequency Currents*, before commencing the study
of their physiological effects and therapeutic indications.

We shall describe the physiological effects of high-frequency
currents under two headings, namely: *General effects* and *local
effects*.

84. General Effects of High-Frequency Currents.
From the first researches of d'Arsonval it has been known that
the general effects of high-frequency currents are identical, no
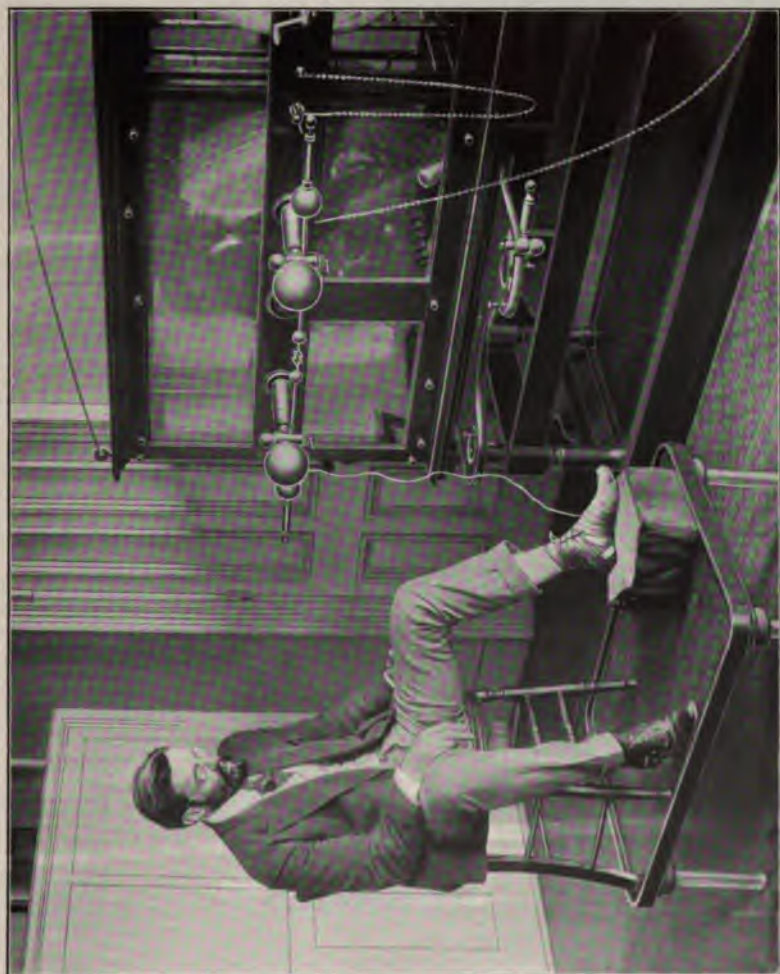matter what method of application is employed. The effects,

PLATE XXXI.

The Wave-Current Applied to Ankle-Joint.

20492

however, differ in intensity according to the method of application employed. Up to the present time three different methods have been used in the study of the general effects of these currents, namely:

1. *Direct Applications.*—A metallic electrode connected with one terminal of the solenoid is applied to the skin of the patient, while the other terminal of the solenoid is grounded (monopolar application) or likewise connected with a metallic electrode and applied to the skin of the patient (bipolar application).

2. *Autoconduction.*—In this method the patient is placed in an oscillating electric field created by a solenoid that completely surrounds him (see Fig. 49, *Electrostatics and High-Frequency Currents*). "The tissues of the patient are the location of extremely energetic induced currents due to the frequency of the electric source; they act like short circuits and are traversed by inductive currents of high intensity."

3. *Condensation.*—In the third method of applying high-frequency currents the patient is placed on a lounge, as shown in Fig. 48, *Electrostatics and High-Frequency Currents.* The patient in this method constitutes one armature of a condenser connected with one of the terminals of the solenoid; the dielectric is formed by the air contained in the substance of the mattress beneath which is fixed a sheet of metal forming the second armature of the condenser and communicating with the other terminal of the solenoid made of a few turns of thick wire.

4. *Sensory and Motor Effects.*—The effects produced in general electrification by high-frequency currents are best studied in their actions (1) on the sensory nerves, (2) on the motor nerves, (3) on the vasomotor nerves, (4) on the trophic processes, (5) on the micro-organisms and their toxins.

The experiments of d'Arsonval (1893) are now classic; six lamps of 125 volts and .8 ampere were placed in circuit with several individuals. The extremities of the circuit were connected with the two poles of the high-frequency solenoid, the lamps became incandescent when the current passed, but the individuals in the circuit experienced neither motor nor sensory effects. The analogy between these phenomena and static phenomena are striking. If a patient insulated on the static

platform has both poles of the static machine applied directly
to his skin he will experience no sensation,—there will be no
motor reaction, though the plates be revolving at their maxi-
mum of rapidity.   If one electrode is removed a short distance
from the patient's body, a shower of sparks at once occurs
between the electrode and the skin, and these sparks are painful.
The sparks from the high-frequency apparatus of d'Arsonval,
however, produce a certain degree of analgesia that static
sparks do not.

The quantity of energy traversing the circuit was 720 watts,
sufficient to kill a man if it traversed his organism under the
form of an alternating current of low frequency.   With a pow-
erful apparatus for the production of high-frequency currents
the current intensity that can be applied to a patient with-
out producing either motor or sensory effects is about 300
milliamperes.

5.   *Vasomotor Effects.*—The vasomotor nerves on the contrary
are eminently excitable by currents of high frequency.   Under
the action of these currents the blood-vessels in the ear of a
rabbit dilate just as if the sympathetic had been divided.   A
little later the dilatation is followed by an energetic contrac-
tion.   By using the sphygmograph of Marey an identical result
may be demonstrated on man.   In experimenting on man
there is first observed vasomotor dilatation, with lowering of
blood-pressure, but this is soon followed by energetic con-
traction of the vessels, which then remain contracted and the
blood-pressure rises.

85.   All authors who have investigated the action of high-
frequency currents on vasomotor nerves confirm the above
statements.   The importance of this action on the vasomotor
nerves is wholly derived from the rôle of the vasomotor system
in physiology.   The movement of the blood depends on the
heart, but its distribution depends on the vessels.   The vaso-
motor nerves distribute the blood to the organism at the same
time that they regulate its pressure.   By these two mechanisms
they influence temperature, whether local or general, by increas-
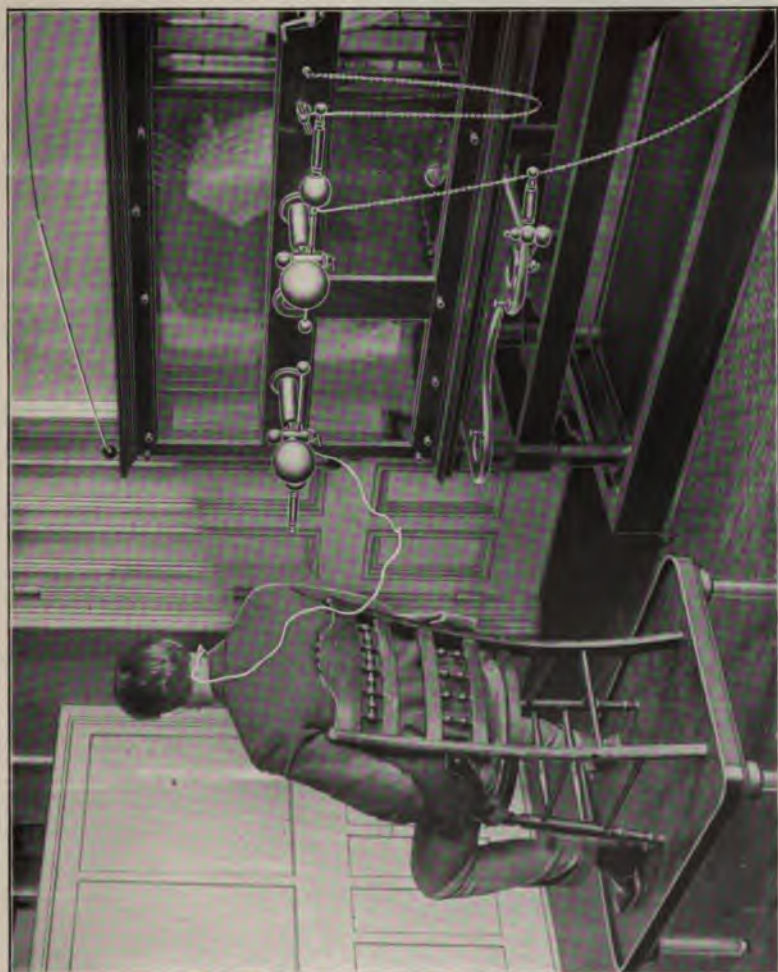ing or decreasing the supply of warm blood to any given region.

PLATE XXXII.

Wave-Current Applied to Spinal Column.

They influence secretions by modifying the pressure in the vessels of the gland, and thus facilitate the physical phenomena of absorption and osmose, or they permit an increased supply of material to the structures of the gland. They influence nutrition in general by the same means that they influence the secretions of glands.

Effects on Trophic Processes.—The most remarkable of the effects of high-frequency currents is the extraordinary activity they impart to the nutritive processes of animal life.

This trophic effect on man and animals has been determined by analyzing the products of respiratory combustion before and after the action of high-frequency currents. The increased tissue-metabolism is shown by the larger consumption of oxygen and the greater elimination of carbon dioxid. The increased activity in nutritive processes has also been determined by urinary analysis. During treatment there is an augmentation of the volume of urine, of urea, or uric acid, phosphates, sulfates, and chlorids eliminated in 24 hours. The hyperactivity of organic combustions can also be demonstrated by measuring the quantity of heat radiated from the body.

In confirmation of the trophic action of high-frequency currents we add the results obtained by weighing animals submitted to the influence of these currents. In the normal state the guinea-pig loses 6 grams of his weight in 16 hours; he loses 30 in the same time under the influence of these currents. Another guinea-pig that lost 6 grams in 5 hours in the normal state lost 24 in the same time under the influence of high-frequency currents. A rabbit has lost 48 grams in 8 hours during the passage of the current and 25 grams only in the same time in the normal state.

In general electrification by high-frequency currents there are therefore produced three principal phenomena.

1. Absence of reaction of motor and sensory nerves.

2. Reaction of vasomotor nerves producing vasodilatation soon followed by contraction.

3. Increased activity in tissue-metabolism.

Effects on Microbes.—The action of high-frequency currents on micro-organisms and their toxins has been demonstrated by

d'Arsonval and Charrin.   They experimented first on diphtheritic toxin by the direct application of high-frequency currents. The diphtheritic toxin was placed in a V-shaped tube in which was inserted two platinum wires.   These platinum wires were connected with the terminals of a small solenoid.   The current was passed through the toxin for 15 minutes and then 2.5 cubic centimeters of the toxin was injected into each of these guinea-pigs and the same toxin through which no current had been passed was injected into three other guinea-pigs to control the experiment.   The three guinea-pigs into which the toxin through which no current had passed was injected died in 20, 24, and 36 hours, while the three injected with the toxin that had been subjected to the passage of the high-frequency current were not even sick.

Experiments were made on the bacillus pyocyaneus.   When the current passed $\frac{1}{2}$ hour the bacillus was killed.   An attenuation of the virulence of the bacillus was obtained in a few minutes.   From these and other experiments d'Arsonval and Charrin conclude: That high-frequency currents attenuate the virulence of bacilli and their toxins.   That the toxins thus attenuated increase the resistance of animals into which they are injected; that is, they become antitoxins.   The results of the beautiful experiments of d'Arsonval and Charrin permit us to hope that it will be possible in a future that is not perhaps distant, to attenuate toxins directly in the organism, without altering the constitutive elements of the tissues, by means of high-frequency currents.

86.   Local Effects of High-Frequency Currents.
The local effects of high-frequency currents have been studied in their actions on (a) sensory nerves, (b) motor nerves, (c) vasomotor nerves, (d) trophic processes.   For local applications of these currents, Oudin's resonator (Fig. 50, *Electrostatics and High-Frequency Currents*), or d'Arsonval's improved high-tension coil (Fig. 51, *Electrostatics and High-Frequency Currents*), or the bipolar resonator of Rochefort, Plate XXXIII, may be used.   The electrodes used in the local application of high-frequency currents are of three kinds: Ordinary metal
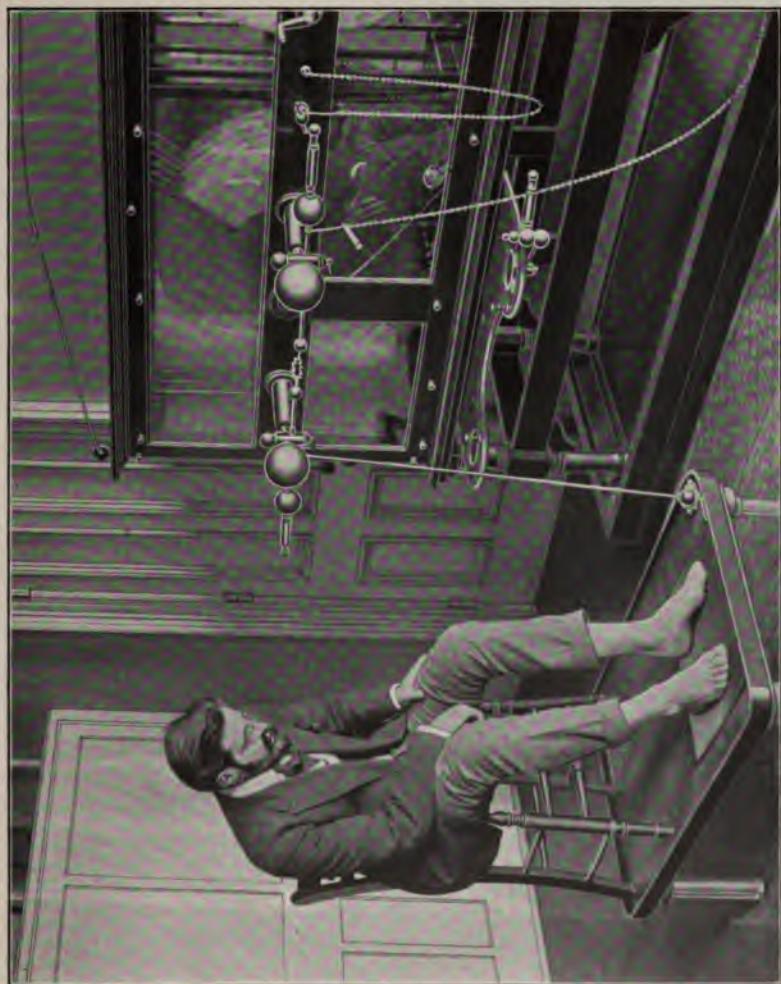
PLATE XXXIII.

Wave-Current Applied to Soles of Feet.

20492

electrodes, condenser electrodes, and vacuum electrodes. High-frequency electrodes are illustrated in Plate XXXV.

Local methods comprise (*a*) direct applications, the patient being placed in shunt with the solenoid; (*b*) spray; (*c*) spark.

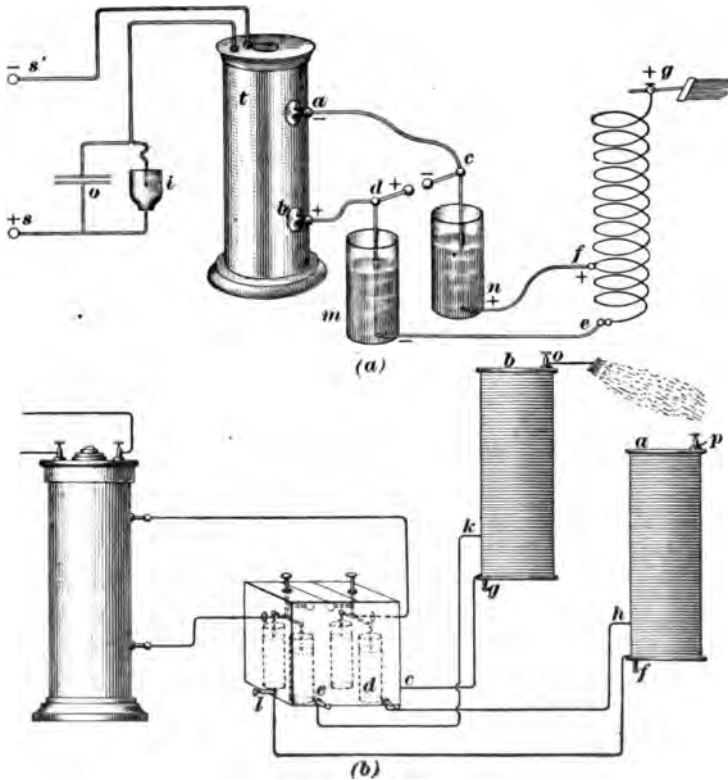Direct applications have been carefully studied by M. Denoyès,

PLATE XXXIV.

(*a*) *Monopolar Resonator with Vertical Transformer (Rochefort).*
(*b*) *Bipolar Resonator with Vertical Transformer (Rochefort).*

who attributes to them (*a*) an analgesic action, (*b*) an absorbent action, (*c*) a vasomotor action, (*d*) trophic action.

If high-frequency currents are applied to the skin by means of a pencil of metallic wires, a shower of small violet sparks

pass between the electrode and the skin producing a prickling, and somewhat painful, sensation. If this application is continued several minutes the skin becomes anesthetic. This
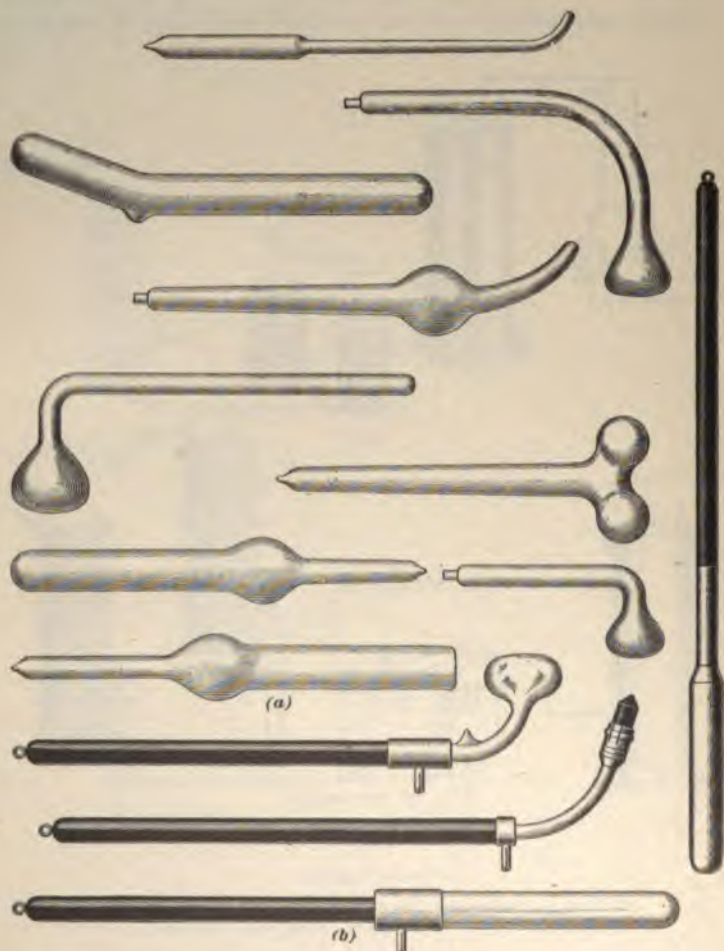
PLATE XXXV.
High-Frequency Electrodes.

anesthesia is superficial and does not last long. Its therapeutic importanceis derived from the fact that it is not only

produced in the physiological state but also in numerous pathological conditions.

Doumer and Zimmerman report cases of anal fissure successfully treated by this property of high-frequency currents. They employed monopolar intrarectal applications by means of a glass rod for about 5 minutes. Oudin, Regnier, and Didsbury have been able, after the application of these currents, to extract, without any pain, molars with inflamed pulps. Doumer has further utilized this property of high-frequency currents in the treatment of painful hemorrhoids, orchitis, and tuberculosis of the prostate to combat the element of pain.

In the general application of these currents, a striking characteristic is that there is no motor reaction. In local applications this is not the case. If the current is interrupted in a point, a spark is produced at each interruption, and if this spark is delivered on a muscle, it will cause contraction of the muscle. Sparks from the resonator determine an anemia of the skin in a circumference of 1 or 2 centimeters. This pallor is followed by the characteristic appearance of goose-skin. If a series of sparks is applied along the vertebral column, the pressure in the arteries will be considerably increased. The spray, particularly from the bipolar resonator of Rochefort, produces an intense vasodilatation of the points or surface submitted to its influence, and a very active and intense rise in arterial pressure. It acts by ameliorating the general state of the patient and by increasing the defensive reactions of the organism.

The monopolar applications of the spray and spark are very often successful in a variety of skin diseases, as eczema, lichen, lupus erythematosus, psoriasis, pruritus, neuralgia, etc. The local actions of high-frequency currents on the vasomotor nerves do not differ from their general action. After prolonged applications of the spray or spark from the high-tension solenoid, lesions are produced analogous to those sometimes observed after certain X-ray exposures. The direct application of high-frequency currents in rabbits is far from having the same innocuity as in man. They always produce very grave phenomena in rabbits, and if the application is sufficiently prolonged, the rabbit dies.

87. Therapeutic Indications.—The remarkable physiological effects of high-frequency currents on the nutritive acts of living tissues seemed to open up some few years ago wide fields for their therapeutic applications. It was thought that there would be a legitimate place for these modes of electrification in diabetes, obesity, rheumatism, gout, and in all diseases characterized by slow nutritive processes. Experience with these currents in the treatment of disease has not responded to the hopes created by their physiological actions. Indeed, a French author and teacher in a recent work states that autoconduction and autocondensation should be discarded and that the direct applications and the currents from the various resonators should alone be employed.

The French authors (Apostoli, Oudin, Doumer) particularly recommended high-frequency currents in the treatment of:

1. Gout, diabetes, obesity, asthma, gall-stones, kidney-stones, rheumatism, anemia. They also recommend their use in malignant tumors.

2. Eczema, acne, furunculosis, herpes, lichen ruber, psoriasis, lupus, erythema. According to Eulenberg good results are obtained in the treatment of all these skin diseases.

3. Neuralgia and functional derangements of the heart.

4. Diseases of the genito-urinary apparatus of both sexes, so also in hemorrhoids and in anal fissures and ulcers.

5. They have also been quite frequently employed in the treatment of tuberculosis of the lungs.

The duration of all applications varies from 3 to 15 minutes, and the applications are repeated daily or on alternate days.

TECHNIQUE AND PHYSIOLOGY
OF DIRECT CURRENTS.

INTRODUCTION.

THE HUMAN BODY AS A GENERATOR OF ELECTRIC CURRENTS.

DISCOVERY OF CURRENTS IN NERVES, MUSCLES, AND GLANDS.

1. Analogy Between Electric Organs of Certain Fishes and Human Muscles.—Before discussing the functions of human tissues as generators of electric currents, we shall briefly consider the electric phenomena produced by electric fishes. These phenomena interest the electrotherapeutist because of the analogy that exists between the manner in which the electric organs of the fish produce electric discharges and that in which a muscle that contracts determines a loss of potential.

The principal known electric fishes are the gymnotus, or electric eel; the malapterurus, or sheath fish; the torpedo, and several other species of rays. The electric organs of these fishes were discovered by Redi. They are flattened kidney-shaped organs situated at each side of the head. They are formed of hexagonal prisms, each of which is constituted by a large number of cells. Each cell is filled in part by a granular mass, probably of a protoplasmic nature in which the nerve ramifies, and by an amorphous fluid substance distributed over the nerve-filaments. Each electric organ receives four nerve-trunks. If these nerves are cut on one side, the

corresponding organ cannot give electric shocks; it is paralyzed like a muscle whose motor nerve has been divided. If the peripheral end of the divided nerves is stimulated, an electric discharge is produced. These phenomena are exactly analogous to those observed in a muscle when its motor nerve is divided. When the motor nerve is divided, the muscle is paralyzed, and if the peripheral end of the divided nerve is stimulated, the muscle contracts.

In comparing the structure of electric organs with that of muscles, M. Marcy has pointed out certain resemblances; the fascicle of electric prisms resembles a fascicle of muscular fibers; each electric prism is formed of superimposed cells resembling somewhat the superimposed disks of striated muscle-fibers.

If the torpedo is submitted to the influence of a narcotic—opium or belladonna—the energy of its electric discharge is diminished or annihilated; while it is increased by convulsive agents—strychnin in particular. The electric discharges of these fishes occur only under the influence of their will or under that of an artificial excitant—mechanical, electrical, or chemical. These organs, then, produce an electric current when they are stimulated either by their will or artificially. In this respect they produce electric energy precisely as the muscles produce mechanical energy.

2. The electric discharges of these fishes have been explained in several ways. Ranvier compared the electric organs of the fish to a battery of galvanic cells or condensers. The most acceptable theory is that given by d'Arsonval; it is as follows: in the arrangement of the electric cells and in their composition are all the conditions desirable for the production of electric currents of high tension by the phenomenon of Lippman. The protoplasmic base of each cell excited by its nerve, is electrified negatively (*negative oscillation*) due to the variation of the superficial tension of the protoplasm, and the non-protoplasmic substance is electrified positively. The superposition of the cells connects these elements for tension or in series. There are several millions of these cells in one column. Each individual negative oscillation is, therefore, multiplied by the number of

cells in a column, which accounts for the tension of each dis-
charge. There are also several millions of columns connected by
poles of the same name, which accounts for quantity in each
discharge.

In order to demonstrate experimentally his theoretical views,
d'Arsonval took a tube of caoutchouc and separated it into a
series of compartments by means of porous disks. At the level
of the porous disks he wound the tube tightly with pack thread.
Each compartment of the tube was filled with a stratum of
mercury beneath and one of acidulated water above. When
this tube was suddenly lengthened, both extremities being held,
a shock was experienced. If a weight was suspended from the
inferior extremity of the tube and the whole system was caused
to oscillate up and down, an alternating current was produced.

A torpedo or gymnotus placed in water gives very strong
shocks, at a distance, to other fishes placed in the same water
with it. It does not, however, experience any shock itself.
The torpedo, according to Marey, supports without reaction
very strong discharges from an induction-coil. These fishes are
then mithridatic with regard to electricity as the viper is with
regard to the poison it secretes.

3. Generation of Electricity by Organic Tissues.
Besides these specialized organs of certain fishes, all tissues of
living organisms are capable of producing electric currents.
By means of very delicate measuring instruments, it-is now
possible to perceive the existence and determine the direction
of these currents. The currents in nerve- and muscle-tissue
have received the most attention. Indeed a score of illustrious
physiologists of the 19th century passed a good part of their
lives in the investigation of nerve- and muscle-currents.

From the celebrated controversy between Galvani and Volta
we inherit two important facts: namely, the invention of the
galvanic battery by Volta, and the discovery of animal electricity
by Galvani.

4. Origin of Electrophysiology.—Electrophysiology
dates from the following simple experiment performed by
Galvani. He separated the sciatic nerve of a frog from its

lumbar attachment, and by means of a glass rod applied the
cut end of the nerve to the exposed gastrocnemius of the frog;
the muscle contracted. Galvani first observed (1772-74) that
if he brought the exposed nerve and muscle of a frog in contact
by means of a metallic arch, homogeneous or heterogeneous,
the muscle contracted. He concluded that the current was
generated in the muscle, and he named the electricity thus
developed, *animal electricity*.

Volta contested the interpretation given by Galvani, and
affirmed that the electric current producing the contraction was
generated not in the muscle but in the metallic arc. By char-
ging a condenser, Volta demonstrated that the contact of two
metals produced an electric current and constructed the battery,
which is the origin of all that have since been made. Galvani
now omitted the metallic arc and simply touched the exposed
muscle with the divided end of the nerve; the muscle con-
tracted. To these simple experiments are due the invention
of the galvanic battery and the discovery of animal electricity.

Humboldt (1799) repeated the experiments of Galvani on a
large number of different animals; he examined the influence
of the current on the intestines, on the heart, and on himself.

In 1827, Nobili invented his galvanometer and studied the
current in the nerve and muscle of the frog. He considered
the frog current as thermoelectric in origin due to inequalities
in temperature in nerve and muscle caused by evaporation.

In 1844, Matteucci published his work on "The Phenomena
of Animal Electrophysiology"; and in 1848 a work appeared by
Dubois-Reymond on "The Electrophysiology of Motor Nerves
and Muscles."

Matteucci attributed nerve- and muscle-currents to chemical
action. In opposition to Matteucci, Dubois-Reymond attrib-
utes these currents to vital phenomena, subordinate to the
vitality of tissues and ending with their death. To the chemical
theory of Matteucci he opposed his famous conception of
electrotonus.

Following Dubois-Reymond a large number of German authors
investigated these currents. Among these may be mentioned
Eckhard and Pflüger, who condensed all previous knowledge of

muscle-contraction in a synthesis known as the contraction laws
of Pflüger, Baierlacher, Remak, Erdman, Breuner, Benedikt,
Neumann, Rosenthal, Ziemssen, and Erb. These authors
occupied themselves with the electrophysiology of the muscular
system. Gerhard, Eulenberg, Beard, and Rockwell investigated
the electrophysiology of the great sympathetic. Ritter, Brenner,
Neftel, Eulenberg, and Erb studied the reaction of the retina
and the optic nerve. De Watteville and Bernhardt investigated
electrocutaneous sensibility.

All investigators agree as to the reality of the existence of
these currents; they are not, however, in harmony as to the
conditions of their production. For Dubois-Reymond, these
currents always exist in the muscles, injured or non-injured.
Herman declares emphatically that they cannot be demonstrated
in the intact muscle, that they exist only in the traumatized
muscle and that in this case the longitudinal surface is always
positive and the injured surface negative. These currents are
known in physiology as *currents of nutrition*, or *currents of rest*,
because they manifest themselves when the muscle is inactive
and are thought to be due to the nutritive process going on in
the muscle. If, now, the muscle is excited by some means—
chemical, mechanical, or electrical—it contracts and the needle
of the galvanometer is deflected in the opposite direction,
demonstrating the existence of an electric current, the so-called
negative oscillation of Dubois-Reymond.

**5. Relation of Electric Currents to Muscular Con-
traction.**—When a muscle contracts it produces heat and
accomplishes work, physiological or mechanical. Further, it
produces an electrical current. We have seen that when the
cut end of a nerve is brought in contact with a muscle, the
muscle contracts. An electric current having its origin in
the muscle excites the nerve (in precisely the same manner
as a current from a battery of Leclanché cells) and produces
muscular contraction.

Take a piece of fresh muscle, cut it in two, and connect the
surface of section with the longitudinal surface of the muscle
to a galvanometer by means of two wires; the needle of the

galvanometer will be deflected, demonstrating the passage of a current. If a telephone is substituted for the galvanometer the receiver will vibrate, producing a sound.

The same experiment made on a segment of exsected nerve produces the same result; the needle of the galvanometer is deflected. If the nerve is stimulated while the current of rest is flowing, the needle of the galvanometer will show the existence of the current of action or negative oscillation. These same currents of rest and currents of action can also be demonstrated in non-striated muscular tissue and in glands. The maximum difference of potential for muscles, according to Helmholtz, is .035 to .075 of a Daniell element and for nerve .022 to .026.

There are then two currents in nerves, muscles, and glands with which illustrious physiologists and physicists have been much concerned, namely: (1) The current of rest, also named the constant current or current of nutrition; (2) the current of action always perceived when a muscle, a nerve, or a gland is in an active state.

We have already seen that the existence of the current of nutrition in uninjured tissues and through the unbroken integument is denied by many observers, chief among whom is Herman. Concerning the existence of the current of action or the current of function in living tissues, the so-called negative oscillation of Dubois-Reymond, there exists little or no doubt among physiologists. Even Herman does not directly deny its existence. The current of action was demonstrated in the following manner by Dubois-Reymond. Nonpolarizable electrodes connected with a galvanometer were placed in two vases containing a weak saline solution. His hands were plunged into each of these vases. When he contracted the muscles of his arms he observed a deflection of the galvanometer needle, indicating a current flowing from the arm at rest through the galvanometer to the arm in action. In other words, when a muscle contracts it produces an electric current, and the electric potential of the contracted muscle is demonstrated.

For d'Arsonval the current of rest or nutrition has an incontestable existence. He regards this current as a corollary of the

chemical function of protoplasm; in the tissues protoplasm behaves like zinc in the galvanic cell. The intensity of the current is in proportion to respiratory phenomena. D'Arsonval observes that although the currents detected by him are very feeble, so feeble that their existence is denied by the majority of investigators, they represent the infinitely small part of the currents produced in the organism. They are in reality derived currents. In the intimate structure of the tissue these currents are on short circuit and are only recognized in the form of heat. The chemical reaction of protoplasm produces an electric current, and the heat of the organism is a secondary transformation.

This is, according to d'Arsonval, the common mechanism of the production of animal heat. He compares the production of heat in the animal organism to the production of heat in a galvanic cell. There is, first, chemical action with the production of an electric current, and as a result of the flow of the electric current heat is produced.

When the rôle of these currents will be better known an immense step will have been taken in electrotherapy. Our tissues may be compared to an infinity of membranes separated by fluids of different densities. It is very probable that the currents inherent in muscles, nerves, and glands accelerate osmotic changes in the body. We know that current from external sources can be made to penetrate the human organism, and we may therefore hope to be able to modify the inherent currents of the tissues and in this way to increase or diminish the activity of cell life.

6. Effect of Muscular Contraction on the Blood.—A voluntary muscle does not seem capable of spontaneous contraction. For contraction it requires the stimulation of the will or an artificial excitation. When the will is no longer able to act either on account of disease or injury, artificial excitation must be resorted to. An electric current is the only artificial excitation that will effectively contract a muscle in this condition. The importance of muscular contraction is evident from the changes it produces. Muscular contraction modifies profoundly the composition of the blood: it renders it more venous than it

is in a condition of repose.   During contraction there is marked intramuscular vasodilatation, the muscle contains more blood, and the blood flows more rapidly than during repose.   Muscular activity reduces tension in the artery and increases tension in the veins.   The property of a muscle to contract is inherent in muscular tissues and persists after its nerve-supply is cut off.

RESISTANCE OF HUMAN BODY TO ELECTRIC CURRENTS.

7.   There are two very important factors to be considered in direct-current applications to the human body that must be thoroughly understood in order to intelligently apply these currents with a view of utilizing their physical, chemical, and physiological properties, or their empiric indications, in the treatment of disease.   We refer (1) to the electric resistance of the body as a whole and to the electric resistance of the individual tissues of which the body is composed, and (2) to the current-density in different parts of the circuit, and particularly at the points or surfaces of application of the electrodes.   The human body is not a simple homogeneous conductor: it is a complex conductor of three dimensions essentially heterogeneous.   It is not reasonable, therefore, to assign to it an electric resistance as precise and determined as can be done for a simple wire conductor.   When the electric resistance of the body as a whole is referred to, what is meant, in reality, is the resistance of the epidermis.   When the resistance of the epidermis is overcome, the current will be divided among the various tissues of the body in an inverse ratio to their resistances.   The dry epidermis is an insulator much like glass or ebonite.   Ohm's law $C = \dfrac{E}{R}$ teaches us that the value of the factor R modifies the rate of flow, the quantity, and the energy of the current.   It is important, therefore, that we know, at least approximately, the resistance of the body as a whole and the resistance of the individual tissues.

The resistance of the body as a whole has a variable value, since it depends on (a) the potential of the current used, (b) the duration of the application, (c) the sectional area of the electrodes, (d) the pressure exerted on the tissues, (e) the

degree of moisture of the electrodes, (*f*) the region examined, (*g*) the condition of the skin—dry, moist, vascular.   D'Arman states that in a healthy individual, in the usual conditions of electrotherapeutic applications with electrodes of the usual size, and a current-strength of from 5 to 30 milliampers, the body resistance varies between 30,000 and 800 ohms.

By the method of substitution, Larat calculated in twenty patients the resistance during intra-uterine galvanization. With a large electrode, measuring 350 square centimeters, placed on the skin and the usual metallic electrode in the uterus, and using a current-strength of from 25 to 50 milliamperes, the resistance oscillated between 200 and 600 ohms. The resistance becomes extremely feeble when the epidermis is entirely suppressed, as in bipolar electrolysis when two needles slightly separated are plunged into the tissues.

M. Dubois, of Berne, gives the following table of resistances:

From wrist to forearm	400 ohms.
From wrist to arm	460 ohms.
From wrist to back of neck . .	690 ohms.
From wrist to sole of foot . .	900 ohms.
From one foot to the other . .	900 ohms.
From one hand to the other .	900 ohms.

M. Weiss gives the following table to show the influence of current-strength on the diminution of resistance:

TABLE 1.

Intensity. Milliamperes.	Resistance. Ohms.	Intensity. Milliamperes.	Resistance. Ohms.
2.75	1,330	3.00	1,200
6.00	1,250	6.50	1,110
11.50	1,170	10.00	1,065
18.50	1,145	19.50	1,040
11.50	1,160	9.40	1,100
5.50	1,210	5.50	1,160
2.25	1,260	2.25	1,220

The individual experimented on held one electrode in each hand.

The resistance of the body in the hydro-electric bath is about 300 ohms.

8. Resistance of Individual Tissues.—The total resistance of the body is a matter of secondary importance to the electrotherapeutist, because with a reliable milliammeter in circuit the current-strength is always indicated in absolute units. The resistance of the individual tissues is, on the contrary, of the utmost importance. None of the tissues of the body are what physicists call good conductors. Muscular tissue, the best conducting tissue in the body, has 100,000 times more resistance than mercury. If the specific resistance of the muscular tissue is represented by 1 the resistance of the other tissues may be represented as follows:

Muscle	1.0	ohm.
Tendon	1.8 to	2.5 ohms.
Nerve	1.6 to	2.4 ohms.
Cartilage	1.8 to	2.3 ohms.
Bone	16.0 to	22.0 ohms.
Skin deprived of its epidermis	100.0 to	500.0 ohms.

9. Influence of Liquid in Tissues on Resistance. The resistance of organic tissue does not depend on the tissue itself but on the amount of liquid it contains. Eckhard has given the following percentages for liquids in the different tissues:

Muscle	98 per cent.
Tendon	62 per cent.
Cartilage	70 per cent.
Nerve	66 per cent.
Bone	7 per cent.

To demonstrate the influence that the quantity of fluid in any tissue has on its conductivity, slowly dessicate the tissue and pass through it at intervals an intermittent current to avoid the effects of polarization. It will be found that as the process of dessication proceeds the resistance will increase, until finally when dessication is complete, the tissues may be considered an

insulator. If the dessicated tissue is now placed in an artificial serum its normal conductivity will soon be restored.

10. Matteucci's Demonstration of the Conductivity of Organic Tissues.—Matteucci demonstrated the conductivity of the different organic tissues in the following manner: Taking sections of equal dimensions of nerve, bone, and muscle he placed them end to end on a glass plate, making them part of a circuit through which a current of constant intensity is flowing. He prepared a cork by inserting a platinum needle through each end and connecting the platinum needles to the terminals of a galvanometer by means of two wires. It is evident that when the platinum needles are plunged into either the nerve, bone, or muscle, part of the current in the principal circuit will pass through the galvanometer in the form of a derived current. Matteucci found that when the platinum needles were plunged into the muscular tissue, the galvanometer needle was only slightly deflected; that when they were inserted into the nerve, the deflection of the galvanometer needle was four times greater; but that the deflection was at a maximum when the platinum needles were inserted into the bone.

11. The Law of Kirchoff.—These circuits improvised by Matteucci represent the composition of the circuits which the electrotherapeutist must consider in applying electric currents to the human organism. The distribution of the currents in these circuits is determined by the law of Kirchoff and may be stated as follows: *The intensity of the principal current is equal to the sum of the intensities of the derived currents.*

We know that the intensity of any current is inversely proportional to its resistance. Applying these data to electrophysiology we find that the largest part of a current applied to the body will pass through the muscles, a smaller part through the nerves, and a still smaller part through bones. From these facts we may make some very practical deductions to guide us in electrotherapeutic work.

12. Conditions Determining Resistance of Human Tissues.—The ordinary physical conditions that determine the

resistance of human tissues are modified by (a) vascular action, (b) polarization in the neighborhood of the electrodes, (c) polarization in the interpolar tissues, (d) the electric capacity of the region included between the electrodes.

Vascular conditions modify considerably the resistance of the circuit. The absorbent part of the electrode may be thoroughly saturated and the skin thoroughly cleansed and moistened, yet after a few minutes' application of the direct current, the rate of flow increases several milliamperes. This diminution of resistance is due to the increased vascularity beneath the electrodes. In pathological conditions in which there is a dilatation of peripheral vessels, the electric resistance is considerably decreased.

In the immediate neighborhood of the electrodes there is an intense polarization due to electrolytic products set free. This polarization creates an E. M. F. that acts in opposition to the primary current and has the same influence as if the resistance of the circuit was increased.

Polarization of interpolar tissues also increases the resistance of the circuit. Indeed, one of the first effects produced by a current in an electrolytic conductor is the production of a counter E. M. F. due to polarization.

The influence of various pathological conditions on the electric resistance of the body has been recently investigated by L. Courtadon, and his conclusions in the main confirm those of Vigouroux and other investigators.

From his researches, L. Courtadon concludes as follows: There is a diminution of resistance in Basedow's disease, neurasthenia, chorea, melancholia, edema, and in myopathic affections with atrophy or pseudohypertrophy. The resistance is increased in hysteria, in paralysis accompanied by reduction of temperature, and in epilepsy. It is also increased in scleroderma, elephantiasis, beriberi, in cachexia with loss of flesh, in atrophies due to diminution of section of muscular conductors, and in various effusions. The resistance is also increased in fevers. The increased combustions produce not only heat, but also animal electricity which polarizes the tissues of the patient.

13. Importance of Considering the Resistance of Tissues.—The specific resistance of the different tissues of the body should be carefully considered in every electrotherapeutic application. Neglect to do so in the past will account for many indifferent results. Specific tissue resistances are of capital importance when the question is the application of the electric current to structures enclosed within bony walls, as, for example, the brain and spinal cord. The calculation is very simple to determine the current-strength that will reach the spinal cord when the current-strength in the principal circuit is only 8 or 10 milliamperes applied, as it frequently is, by means of a small hand electrode. Still keeping in mind the ratio of the specific resistances of the tissues of the body, it will be seen how little of the current can possibly pass through the brain tissue when but from 4 to 6 milliamperes are flowing in the principal circuit. We repeat that since the advent of reliable milliammeters to indicate in absolute units the current-strength in the principal circuit, the resistance of the body as a whole has become of secondary importance, whereas the ratio of the specific resistances of the tissues of the body has assumed a very practical rôle in the successful application of the direct current in therapeutics.

RELATION OF CURRENT-DENSITY TO SURFACE AREA OF ELECTRODE.

14. The sensory effects, the motor effects, and the electrolytic effects of the unbroken flow of the direct current depend on the current-density; that is, the ratio of the current-strength to the sectional area of the conductor through which it flows. The absolute value of current-intensity is not of great value in itself; it is necessary at the same time to consider the surface area of the electrode.

If D represents density, C the current-strength, and S the surface area of the electrode, the following formula will enable us to ascertain the current-density, $D = \frac{C}{S}$; the larger that S is, the less will be the density; and inversely.

The density of a current at any part of its circuit is inversely proportional to the sectional area at that part of the circuit.

Current-density is generally neglected in the commercial applications of electricity. The circuit for commercial currents is homogeneous and is composed of good conducting material. In electrotherapeutics, the circuit traversed by the current is complex—formed of conductors (rheophores, electrodes, and the human body) whose cross-section and conductivity differ widely; the density is therefore different in each of these parts. The importance, in electrodiagnosis and in electrotherapeutics, of the current-density is only second to that of current-intensity. The current-intensity is always indicated in absolute units by the milliammeter intercalated in the circuit. If, now, we know the surface area of the electrode, the current-density is expressed by a fraction whose numerator and denominator are the current-intensity and the surface area of the electrode, respectively, or

$$\frac{current\text{-}intensity}{surface\ area\ of\ electrode} = current\text{-}density.$$
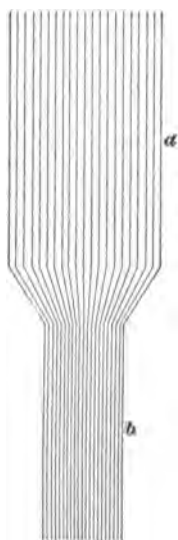
Fig. 1.

Place two electrodes 10 and 30 square centimeters in area very near each other on the flexor surface of the forearm so that they can be connected, now one, now the other, with the negative pole of the direct current while the indifferent electrode is placed on the sternum. With the electrode of 10 square centimeters in circuit, allow 3 milliamperes to pass. We may now suppose that these 3 milliamperes represent 1,000 lines of flow, or flux lines, and that they pass through the electrode of 10 square centimeters in area and the subjacent skin. Now place the electrode of 30 square centimeters in circuit and allow the same current-strength to pass; the 1,000 flux lines represented by the current-strength will spread out over three times the surface; the current has, in the first instance, three times the density of the second current.

15. Erb has compared the lines of flow of an electric current to a girl's loose hair, which may be gathered into a thin coil

without changing the number of hairs, Fig. 1.   In a narrow con-
ductor, Fig. 2, these lines of flow are straight lines from pole
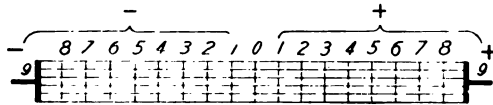
FIG. 2.
Shows Distribution of a Current of .18 Volts.

to pole.   The dotted lines in the figure are lines of equal poten-
tial.   Lines of equal potential, in this case, of electricity, are
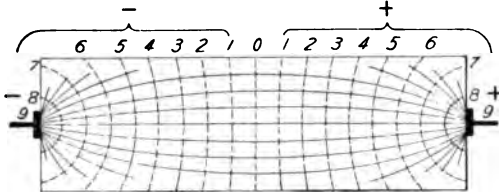
FIG. 3.

already understood when it is known that they are analogous
to the edges of the steps of a staircase down which a water
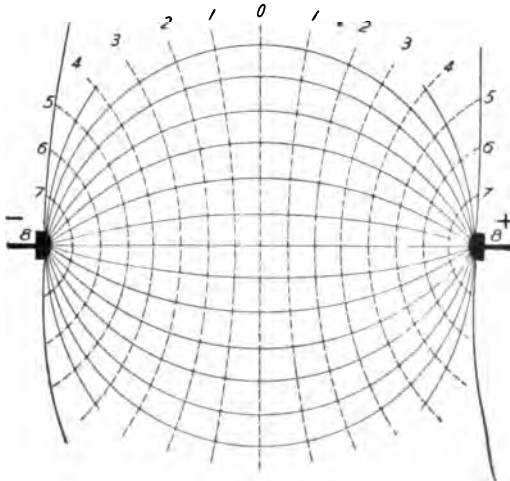
FIG. 4.

current is flowing.   It is assumed that the middle step is zero,
or at the level of the earth.

In a wider conductor, Fig. 3, all the flux lines with the exception of the central one tend to curve, as the potential lines must be curved at right angles. When the current is passed through a large conductor like the human body, Fig. 4, the equipotential lines become arcs of small circles. The lines of flow traverse the conductor as before, crossing the equipotential lines at right angles.

According to Erb, the subject of current diffusion, or its converse, current concentration, constitutes the quintessence of electrotherapeutic technique. The object almost always is to localize the current in a certain density upon different parts of the body, to determine the irritability of motor points and muscles in diagnosis, or to demonstrate the sedative properties of the current in therapeutics. This we can only do by having clear ideas as to current-strength and density.

16. There are two very important questions in the application of electric currents in medicine and surgery, namely: (1) The size of electrodes to be chosen, and (2) the strength of current to be used.

These two questions are very closely related, since they form a fraction whose value is the current-density. On their answer depends whether the patient shall or shall not be submitted to pain during an electrical application, and whether he shall or shall not receive a burn followed by an indelible scar. It may be stated, as a general rule, that whenever there is really pain at the surfaces of application of the electrodes (except in cases of hyperesthesia and alteration in the epidermis) it means that the current-density is too high and that the intensity should be reduced or the area of the electrode increased.

Boudet calculated that the quantity of electricity that could pass through an electrode having a surface area of 500 square centimeters, without producing pain, during 10 minutes, was equal to about $\frac{1}{2}$ horsepower. The intensity of the current was 25 milliamperes, that is $\frac{1}{20}$ milliampere per square centimeter of surface. If an electrode having a surface area of 5 square centimeters is used, and it is desired to use the same current-intensity, it will be found necessary to increase the E. M. F. in

proportion to the diminished size of the electrode. In these conditions the pain produced by the small disk electrode carrying 25 milliamperes is so acute that it becomes insupportable. In these two cases the current-strength and the duration of application are the same, yet the local effects are entirely different. In the first case, there is hardly any sensation and only slight reddening of the skin; in the second case, there is acute pain and chemical destruction of tissues. The difference in local effects is due to two causes: (1) Increased E. M. F. necessitated by the increased resistance of the circuit; (2) increase of current-density at ·the surface of contact between the electrode and the skin.

In the first case, there is $\frac{1}{20}$ milliampere to the square centimeter of electrode surface, and in the second case there are 5 milliamperes to the square centimeter of electrode surface; in other words, the current-intensity per unit of surface is one hundred more in the second than in the first case.

17. The following table prepared by Boudet is of especial value to beginners in electrotherapeutic work, as it gives the average value of the current-intensity per unit area of electrode surface that may, with safety, be used in electrical applications:

TABLE 2.

Size of Electrode. Square Centimeters.	Density of Current. Milliampere.	Size of Electrode. Square Centimeters.	Density of Current. Milliampere.
1	1.00	50	.26
2	.75	100	.19
5	.60	300	.08
10	.47	500	.05
25	.30		

An examination of this table shows that the value of the electric density should diminish as the current-intensity increases. If an electrode having a surface area of 1 square centimeter can be applied to the skin for 10 minutes with a current of 1 milliampere it does not follow that 20 milliamperes

can be applied to the skin for the same time through an electrode having a surface area of 20 square centimeters. In this latter case the pain would be intolerable and a scar imminent. For a current-strength of 20 milliamperes, the electrode should have an area of 100 square centimeters. Larat explains this anomaly in the following manner: He considers each square centimeter separately and supposes that the sensory nerves of the skin are irritated, not only in the surface of contact of the electrode but also for some distance from the periphery of the electrode. The added irritation of each additional square centimeter falls on tissues whose irritability is above the normal. There is a multiplication of effects in each square centimeter added to the surface area.

The application of this table in practice is very simple. All electrodes should have their surface area permanently stamped on them. When an electrode of a certain size is selected it is only necessary to refer to the table to see at once the current-density per unit area of surface. If the electrode selected has a surface area of 100 square centimeters, the current-density per square centimeter is .19 milliampere. Multiplying these two factors together will give the current-intensity to be used with an electrode having a surface area of 100 square centimeters. This current-strength, according to Boudet, should not be exceeded during an application of 10 minutes.

COMPOSITION OF PATIENT'S CIRCUIT.

18. The patient's circuit is composed of a rheophore leading from the positive binding-post on the switchboard to the electrode (metal plate or disk covered with some absorbing material applied to the patient's body), the patient's body, and another electrode, metal plate or disk with appropriate covering, and the rheophore that leads to the negative binding-post on the switchboard. In analyzing this circuit with reference to resistance and current-density, we find that the current-density is greatest in the rheophores on account of their small sectional area; and that the resistance is least on account of the high specific conductivity of copper of which they are composed.

The conductivity of the electrodes, metallic plates or disks, is very good even when they are covered by amadou, chamois, or gauze thoroughly saturated with water.   Indeed an increase in the number of layers of chamois or gauze increases the conductivity of the electrode by retarding evaporation.   The density in the electrodes due to their increased surface area is considerably less than in the rheophores, but still is greater than in the patient's body.

The density in the patient's skin in immediate contact with the electrode has the same value as that in the electrode itself. This density, therefore, varies with the density in the electrode applied to the patient.   It is in this part of the circuit that the current encounters its maximum of resistance.   The skin forms in itself the largest part of the total resistance. of the circuit. The greatest expenditure of energy is always at the point of greatest resistance; therefore, the greatest amount of electric energy in the circuit is absorbed by the resistance of the skin, and if we desire that a sufficient quantity of current penetrate to the deeper organs of the body, we must use a considerable quantity of current and diminish as much as possible the loss of energy occasioned by the skin.   In order to accomplish this we must use currents of high intensity and electrodes of large surface.

APPLICATION OF DIRECT CURRENTS
TO THE HUMAN BODY.

PHYSIOLOGICAL EFFECTS OF CURRENTS.

19. The student having already learned how the direct current is generated, and how it is measured and controlled, we shall now describe the effects produced by the direct current when it is applied to the human organism. These effects may be divided into two classes:

1. Effects common to the human body and inanimate electrolytic conductors. These effects are *cataphoric* and *electrolytic*.

2. Biological effects due to the human body being a living animal organism. These effects are *contractile* and *electrotonic*.

The physiological effects will be totally different, depending on the manner in which the current is permitted to flow in the patient's circuit. The current may enter the patient's circuit gradually, with slight variations until the required intensity is reached; this intensity is maintained for 5 or even 15 minutes according to indications, when the current is gradually withdrawn. This is known as the steady flow of the direct current and is characterized by electrotonic, cataphoric, and electrolytic effects. The maximum intensity may be suddenly attained and as suddenly return to zero. This is the interrupted flow of the direct current and is characterized by contractile effects. These variable periods of current flow, sudden production of maximum intensity, and sudden return to zero, are named opening and closing periods.

The effects produced by the steady flow of the direct current will vary with the electrodes used and will depend on whether the electrodes are covered or bare, protected by chamois or gauze, or having the metal surface of the electrodes in contact with the mucous or cutaneous surface, or plunged directly into the tissues of the body.

The physiological effects of the direct current are best studied: (1) On motor nerves and striated muscles; (2) on sensory nerves and nerves of special sense; (3) on vasomotor nerves; (4) on the pneumogastric and sympathetic nerves; (5) on non-striated muscles; (6) on brain and spinal cord.

20. Action of Direct Currents on Muscles.—If a direct current of a certain density is applied to a muscle the muscle contracts. This is known as *direct muscle stimulation*. If a direct current of a certain density is applied to a motor nerve, the muscles supplied by this nerve contract. This is known as *indirect muscle stimulation*. Muscular contraction does not continue during the whole time that the current flows through the nerve or muscle; it occurs only (1) when the current is made; (2) when it is broken; (3) when the current-strength is suddenly increased; (4) when the current-strength is suddenly decreased; (5) when the current direction is suddenly changed.

It is, therefore, not the absolute value of current-density in a given moment that excites motor nerves and muscles, but rather the rapid change in density. A study of the different excitants of nerves demonstrates that it can be admitted as a general law that: *Excitation is above all a function of the rapidity of variation of the potential of the exciting agent.* The effects produced on motor nerves and muscles by variation in current-density depend on (1) the current-strength, whether feeble, medium, or strong; (2) current direction, whether ascending or descending; (3) whether the current is made or broken. In experiments on animals, Pflüger has very thoroughly investigated these different features and formulated the following laws:

1. *Weak Currents.*—Weak currents produce contractions in both current directions, but on closure only. The irritation on opening is too feeble to produce muscle contraction.

2. *Medium Currents.*—Medium currents produce contraction in both current directions, both on opening and closing.

3. *Strong Currents.*—Strong currents produce contraction on closing with the descending current and on opening with the ascending current.

21. Explanation of Pflüger's Laws.—To understand the contraction laws of Pflüger it is necessary to know what takes place in the nerve when these currents of different strengths and different directions are flowing through it, and also what takes place when the currents are made and broken.   **Fig. 5 is a**

(a)

A   *C*

(b)

C   *A*
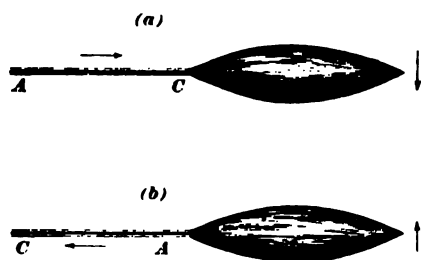
FIG. 5.

schematic representation of motor nerves and muscles in which (*a*) represents a descending current, that is, a current flowing in the direction of the nerve-current from center to periphery; and (*b*) an ascending current, that is, a current flowing in a direction opposite to the nerve-current, or from periphery to center.

In the experiments on the frog both electrodes are placed on the bare nerve.   When a direct current is applied to a nerve it changes both the irritability and the conductivity of the nerve. In the neighborhood of the anode, the irritability is decreased and in the neighborhood of the cathode the irritability is increased.   This changed condition of the irritability of a nerve, while a direct current is passing through it, is known as **electrotonus.**   The increased irritability beneath the cathode is called **catelectrotonus** and the decreased irritability beneath the anode is called **anelectrotonus.**   The difference between anelectrotonus and catelectrotonus varies with the current-strength and continues while the current flows through the nerve.   The stronger the current the stronger will be the difference in irritability.   The changed irritability of a nerve during the passage of a direct current is demonstrated by having a coil-current act on the nerve while the galvanic current is flowing through it.   It will be found that in order to produce a muscular contraction with the coil-current applied to the anelectrotonic area, it will be necessary to advance the secondary much farther over the primary than is required when the coil-current is applied to the catelectrotonic area.

A nerve is said to be stimulated when its irritability is increased. Stimulation of a motor nerve contracts the muscles to which it is supplied. Anelectrotonus diminishes the irritability of a nerve and does not contract muscles.

22. On closing the direct current, catelectrotonus at once appears beneath the cathode and produces muscular contractions. This occurs in both current directions and for feeble and medium currents. On every opening of the direct current there is a sudden change in the relation of nerve irritability; the increased irritability at the cathode disappears and is replaced by a momentary condition of decreased irritability, the cathode therefore produces no contraction when the current is opened. At the anode, however, anelectrotonus appears and there is produced a momentary increase of nerve irritability (negative modification). This disappearance of anelectrotonus and the momentary negative increase of irritability produces muscle contraction; but the muscle contraction produced by disappearing anelectrotonus is not nearly as strong as that caused by appearing catelectrotonus. Appearing catelectrotonus is therefore, according to the experiments of physiologists, a stronger stimulus than disappearing anelectrotonus or negative increase of intensity. With weak currents the stimulus caused by opening the current (disappearing anelectrotonus) is not sufficiently strong to produce muscular contraction; we get therefore contraction only on closing and in both directions of current. In currents of medium strength the stimulus caused by opening the current is stronger and causes contraction; for medium currents, therefore, contractions are produced at opening and closing and in both directions of the current.

With strong currents the irritability beneath the cathode is very much increased and the irritability beneath the anode very much decreased; it is practically lost and the portion of the nerve beneath the anode has lost its capacity to convey electric currents (physiological section). With a strong descending current on closing, appearing catelectrotonus produces powerful muscular contraction. On opening with a strong descending

current, disappearing anelectrotonus acts, but in order to reach the muscle it must pass through the catelectrotonic area, which is momentarily in a condition of negative modification and unable to conduct the opening stimulus to the muscle, hence there is no contraction. For strong ascending currents the stimulus on closing is appearing catelectrotonus, but this cannot reach the muscle on account of the physiological section caused by the anode, hence no contraction. On opening the stimulus is the momentary negative modification of anelectrotonus that causes muscular contraction.
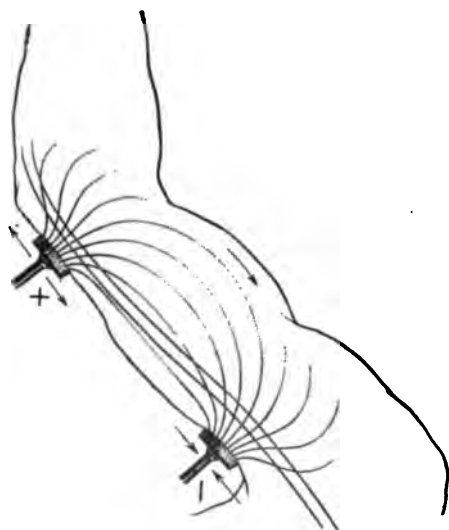
Fig. 6.

An analysis of Pflüger's laws teaches that excitation (muscular contraction) takes place on current rise at the cathode and on current fall at the anode. The stimulus is therefore polar, and it is always anodic on opening and cathodic on closing. It further teaches that the action of the positive pole, anelectrotonus, can be so strong that it destroys momentarily both the conductivity and the irritability of the nerve, hence the phenomena observed in using strong currents as studied in Pflüger's third law.

MOTOR-NERVE REACTIONS.

23. Motor Nerve of Man.—The response of a human motor nerve to electric stimulation is somewhat more complicated than that of the nerve of a frog. The cause of this difference is found in the different physical conditions of the nerves at the time the electrical test is made. The human nerve is

covered by the skin, and is imbedded in tissues having higher
conducting powers than it possesses. Muscular tissue is a much
better conductor of electricity than nerve-tissue. The result is
that the electric current, in obedience to the law of divided
currents, takes the path of least resistance. Directly on enter-
ing the nerve, it leaves and passes along the surrounding better
conductors. When, therefore, a current is applied to a human
nerve, two zones of opposite signs are produced beneath each
electrode. Fig. 6 illustrates the various zones produced by
the bipolar application of a current in the human subject. In
order to avoid this con-
fusion of zones, but one
electrode is placed over
the nerve in making an
electrical examination
of the human subject.
The other, or indiffer-
ent, electrode is placed
on the sternum, the
nape of the neck, or
some other convenient
part of the body. The
sternum is the part
usually selected. On
account of the dif-
fusion of the current,
its direction is not con-
sidered. An examina-

FIG. 7.

tion of Fig. 7 will show that beneath the electrode the current
has four different directions. The physiologist with both elec-
trodes on the bare nerve of a frog obtains two contractions, viz.,
$C C_1$ and $A O$. When an electrode is placed over a human nerve
and a current passes, it produces beneath and immediately
around it two zones of opposite signs. Immediately beneath it,
and of the same sign as the applied electrode, is the polar zone.
Around this, and of opposite sign and greater area, is the peri-
polar zone. Each actual pole applied to the nerve produces two
virtual poles of opposite signs. One electrode applied to the

motor nerve of man produces two zones of different irritability
and density, the appearance and disappearance of which cause
muscle-contraction.   Each pole of the current produces two
contractions, one on closing and the other on opening.

These zones are shown in Fig. 8.   In this figure, the anelec-
trotonic zone is represented by vertical lines and the catelectro-
tonic zone by horizontal lines.

Fig. 8.

24. Test for Electrical Reaction.—To test the electrical
reaction of the motor nerves of man, it is necessary to have
a battery of twenty cells in good working order, with milliam-
meter, rheostat, and commutator in circuit.   The electrode
should be provided with a contrivance for interrupting the cur-
rent; a suitable electrode-handle for this purpose is shown in
Fig. 9.   The standard electrodes of Erb, illustrated in Fig. 10,
are generally used.   They are covered with a wash-leather and
thoroughly saturated with a solution of bicarbonate of
soda in water, 1 teaspoonful to the pint.   Each time the elec-
trode is applied it should be dipped in the soda solution.   With
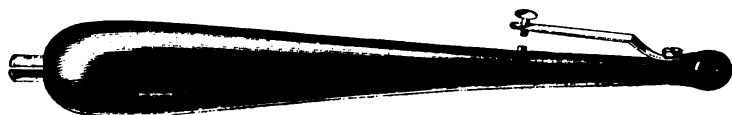
Fig. 9.

the cathode on, say, the ulnar nerve, and the anode on the
sternum, ascertain the number of milliamperes needed to pro-
duce a minimal contraction on closing the circuit.   With the
commutator change the polarity, and ascertain the number of
milliamperes needed to produce minimal contraction on opening
and closing with the anode.   The peroneal, the facial, and the
spinal accessory nerves may be examined in the same manner.
Cathodic closing contraction is always the first to appear.
With a current twice as strong, anodic closing contraction is

produced.   Next in the series, and with a current a little
stronger, comes anodic opening contraction.   The last contraction
to appear is on opening with the cathode, when cathodic open-
ing contraction is produced.   The current-strength necessary to
elicit cathodic opening contraction is generally painful.

Different observers give different current-strengths for the
production of minimal contractions at opening and closing with
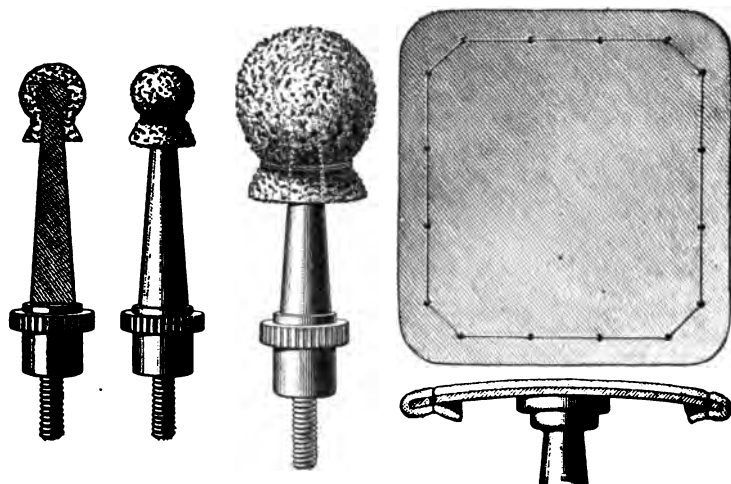
FIG. 10.

each electrode.   The following current-strengths, given by
Doctor Verhoogen, may be taken as those usually required:

$$C\,C_1 - 2.0 \text{ milliamperes.}$$
$$A\,C_1 - 3.0 \text{ milliamperes.}$$
$$A\,O - 3.5 \text{ milliamperes.}$$
$$C\,O - 15.0 \text{ milliamperes.}$$

These figures were obtained from tests on the ulnar nerve.

A very simple experiment that one can easily make on him-
self will confirm the data given by Verhoogen.   Sit in a bath
that represents one pole of the battery and apply the other, or
active pole, to the forearm held out of the water.   In this
way polar action is completely dissociated and the energy of the
contraction is approximately estimated.   In these conditions it
will be found that with a current-strength varying from 1 to 3

milliamperes, muscular contraction is produced by closing the circuit with the negative electrode; while closing with the positive electrode and opening with the negative cause no contraction. With currents increasing from 3 to 5 milliamperes up to the point of toleration, contractions appear at the positive pole on opening and closing and increasing in energy without ever equaling the contraction produced by closing with the negative. With a very strong current (above 15 milliamperes) there is tetanic contraction at cathodic closure, a contraction at anodic closure and anodic opening, and a slight contraction at cathodic opening.
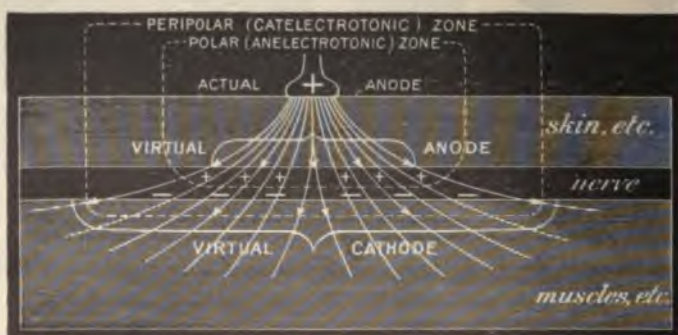
FIG. 11.

25. Normal Polar Formula.—The first contraction in the series is always on closing the circuit with the cathode, and the last on opening with the cathode, anodic opening and closing contractions appearing with intermediate current-strengths. The following is the normal polar formula for healthy motor nerves:

$$CC_i > A C_i > A O > C O,$$

in which
C = the cathode;
A = the anode;
O = the opening;
C_i = the closing.

Fig. 11 explains the order of appearance of these different contractions.

Physiology teaches that appearing catelectrotonus is *per se* a stronger stimulus than disappearing anelectrotonus. The current-density is always greater in the polar than in the peripolar zone. The density of a current varies directly as its strength, and inversely as the area of its cross-section. Thus, beneath an electrode of 2 square inches the current-density would be twice as great as beneath one having a surface area of 4 square inches, the current-strength remaining the same. Cathodic closing contraction is caused by the stronger stimulus (appearing catelectrotonus) in the polar zone, or zone of greater current-density. This explains why it is always first in the series.

26. Anodic closing contraction is produced by the greater stimulus (catelectrotonus) in the peripolar zone, or zone of lesser density. Anodic opening contraction is a weaker stimulus (disappearing anelectrotonus) in a polar zone. Cathodic opening is a weak stimulus in a peripolar zone. Opening contraction for both poles is influenced by the duration of current-flow. The longer the circuit through the anode is closed on the nerve, the deeper the condition of anelectrotonus produced and the stronger the stimulus on opening. The conducting power of the nerve is diminished in the anelectrotonic areas, and may, by sufficiently strong currents, be completely suppressed (physiological section). Voltaic alternations stimulate a nerve more than simple interruptions, because the stimulus falls on the nerve with its irritability increased. There is in each voltaic alternation a summation of cathodic and anodic stimuli.

TABLE 3.

Position of Electrode.	Nature of Stimulus.	Situation of Stimulus.	Result Obtained.
C C₁	Cathodic	Polar	Best stimulus in best region
A C₁	Cathodic	Peripolar	Best stimulus in worst region
A O	Anodic	Polar	Worst stimulus in best region
C O	Anodic	Peripolar	Worst stimulus in worst region

In order to make clearer the varying current-strengths required in eliciting the muscular contractions of the normal polar formula, and also the order of their appearance, the table on the preceding page is given.

If this table is studied in conjunction with Fig. 11, the normal polar formula will be readily understood and easily remembered. The columns of this table are read as follows: In the C.C. the nature of stimulus is cathodic, the situation of contraction is polar, the contraction is therefore caused by the best stimulus in the best region.

27. In normal muscles and nerves, cathodic closing contraction is the first to appear, then comes anodic closing and anodic opening contractions (in the majority of motor nerves and muscles anodic closing contraction comes first); as the cathodic closing contraction has no practical significance, the contractions of motor nerves and muscles may be briefly stated as follows. With the same current-strength, cathodic contraction is normally stronger than anodic contraction. The form of the contraction produced by stimulating a nerve is also of importance. The contraction is quick, that is, it is simultaneous with the opening or closing. It ceases immediately with the variation in current that produced it, and the muscle returns at once to its state of repose. The current may continue through a steady flow, yet the muscle remains quiet. It happens, however, that even with weak currents there is contraction of muscles. It is only when using very strong currents that a contraction tetanus is produced, which lasts during the current is flowing through the nerve or muscle. With a current of usual strength the muscle remains in a quiet form during the steady flow of current. The contraction does not form on direct stimulation of the muscle. The form of the muscular contraction is important when the diseased muscle is in question, as will be seen when degeneration is considered.

EFFECT ON SENSORY NERVES.

28. Characteristic Reactions.—Nerves of sensation and nerves of motion respond to electric stimulus in much the same manner. A motor nerve when stimulated by an electric current causes muscular contraction. A sensory nerve will respond by sensation beneath the electrode, and in the area of distribution of the sensory nerve. A nerve of special sense will respond with a sensation corresponding to its specific function. The gustatory nerve responds with a sensation of taste, the optic nerve with a sensation of light, and the auditory nerve with a sensation of sound. Althaus states that he perceived an odor of phosphorus on stimulating his olfactory nerve. The cathode is more irritating to sensory nerves than the anode. In making an electrical examination of a sensory nerve, it is best accomplished by selecting a nerve without any motor elements. To obtain the normal formula of sensory nerves, the supraorbital is usually chosen. The galvanic current causes a sensation on each opening and closing of the current, and also during the continuous flow. With a weak current there is a sensation of pricking, which becomes burning on increasing the current-strength; while very strong currents produce pain. Part of these sensations is caused by the action of the current on the sensory nerve, and part is produced by the electrolytic action of the current.

29. Test for Reaction of Sensory Nerve.—To test the galvanic reactions of a sensory nerve, place one electrode, well moistened, on the sternum, and the other small, or active, electrode over the nerve to be examined. Gradually turn on the current through the rheostat, closing and opening the circuit. Observe when the first sensation is produced. This will always be found to be on closing the circuit with the cathode. On increasing the current-strength with the anode over the nerve, there will be produced sensation on opening and closing with the anode. A stronger current is required to produce cathodic opening sensation. The normal polar formula for sensory nerves is therefore the same as that for motor

nerves, namely, $C C_1 > A C_1 > A O > C O$. Each interruption of a faradic current produces a sensation like that of a galvanic make or break. With the galvanic current, the severity of the sensation increases with current-strength. The same is true of the faradic current. The greater the electromotive force and current-strength, the more pronounced will be the resulting sensation. With slow interruptions the individual shocks do not blend. When there are 100 or more interruptions per second, there is a benumbing or anesthetic effect produced in the nerve. A rapidly and smoothly interrupted faradic current benumbs the nerves and abolishes pain. Below 1,000 interruptions per minute, each induction-shock may be recognized. Sensitive points on the body should always be considered, so that they may be avoided on electrical examination.

30. Distribution of Sensory Nerves.—The distribution of a sensory nerve in a given area may be mapped out in the following manner: Move a very fine electrode with scarcely perceptible current-strength over the area to be explored. When the electrode is over a sensory nerve, the current will at once appear to be stronger. The benumbing anesthetic effect of the rapidly and smoothly interrupted coil-current is much used in daily practice.

The difference between the sensations caused by the cathode and anode depends on the size of the electrodes. If the anode is small and the cathode large, with the same current-strength, the sensation under the anode will be stronger than under the cathode. This is due to the difference in current-density, on which the physiological activity of the current depends. The current-density varies directly with the current-strength, and inversely as the surface area of the electrode.

31. Optic Nerve.—The optic nerve reacts quite easily to the galvanic current. A weak current passed through almost any part of the head causes flashes of light. The faradic current acts but little, if any, on the optic nerve. To obtain the reactions of the optic nerve, place the indifferent electrode on the nape of the neck, and the small active electrode on the closed eyelid. The electrode represented in Fig. 12 is used

to determine the reactions of the optic nerve.   Through the rheostat gradually turn on 1 or 2 milliamperes, and open and close the circuit.   Have the person examined describe the sensation that he perceives.   Cathodic closing will produce the first sensation of light.   The sensation produced by Cathodic closing and anodic opening is qualitatively the same in the same individual. If cathodic closing produces a reddish light, anodic opening will also produce a reddish light, but in a feebler degree.   Cathodic closing and anodic opening stimuli fall in the same area (polar area), and thus produce the same sensations.   Cathodic closing is *per se* stronger than anodic opening, and both of them are polar stimuli.   Anodic closing and cathodic opening stimuli produce in the same individual the same color of light.   Thus, if anodic closing produces a sensation of bluish light, cathodic opening will produce the same color.   They are both stimuli in the peripolar zone.   Cathodic opening and anodic closing produce qualitatively the same sensations.   They both fall as stimulants in the same area, viz., the peripolar zone.   The normal polar formula for the optic nerve is as follows: $CC_1 > AC_1 > AO > CO$. It is not yet known whether these sensations are produced by stimulating the optic nerve or the retina.
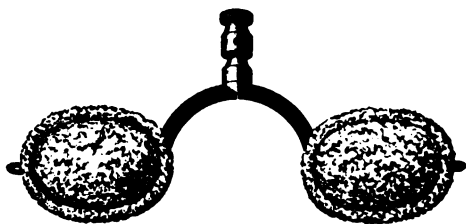
Fig 12.

32.   Test for Reactions of Auditory Nerve.—To test the reactions of the auditory nerve, place a medium-sized well-moistened electrode over the tragus, and the other indifferent electrode on the nape of the neck.   Turn the current on gradually through the rheostat, making and breaking it to obtain the polar reactions.   The reaction of the auditory nerve is more difficult to elicit than are the reactions of the optic nerve.   A greater current-strength is needed, and this often produces disagreeable cerebral symptoms.   The auditory nerve

reacts according to the formula of the physiologist. It responds only to polar stimuli. There is a sensation of sound on closing with the cathode, and, if the current is strong, the sound continues during the flow of the current. The anodic opening sound is short and feeble. The normal formula for the auditory nerve is CC_1 sound, CD (D meaning duration) sound, and AO feeble sound. The auditory nerve gives the polar action of the
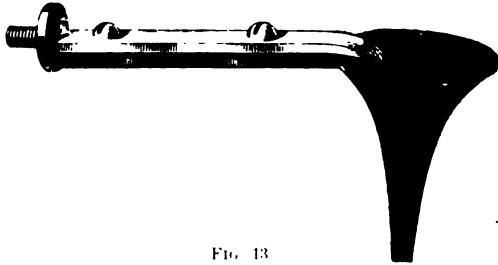
Fig. 13

physiological experiment on the sciatic nerve of a frog. It responds to cathodic closing and anodic opening. This is due to the anatomical position of the nerve. It is surrounded with bone, and bone does not conduct electricity as well as a nerve. If there is a peripolar zone, the current is then so weak that no reaction is produced. The electrodes represented in Figs. 13 and 14 are used in testing the reactions of the auditory nerve.
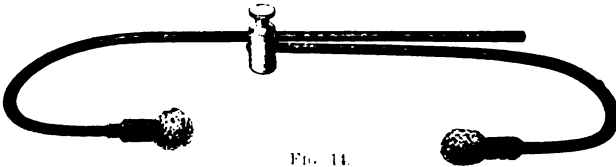
Fig. 14.

33. Importance of Auditory-Nerve Reactions.—The reactions of the auditory nerve are very important from a therapeutic point of view. Tinnitus is a symptom of a large number of aural affections, and is amenable to treatment by the electric current. If the anode or cathode modifies or arrests the sound during the application of the current, the prognosis is favorable, and the treatment should be continued. In diseased irritable conditions of the auditory nerves, the reactions are much easier to obtain.

34. Gustatory Nerve.—This nerve reacts readily to the galvanic current. Flashes of light and galvanic taste are the usual accompaniments of every galvanic application to the head and neck. Place one electrode on each cheek, and turn on the current through the rheostat. Sensations of taste are experienced at both poles. The sensation is more marked at the anode than at the cathode. At the anode the taste is metallic; at the cathode, salty. The difference in taste at the two poles is so marked that it is easy to determine which is the anode and which the cathode. The sensation of taste continues during the passage of the current. It has not yet been determined whether this sensation of taste is due to the liberated acids and alkalis at their respective poles, or whether it is due to the action of the current on the nerves of taste or on the end-organs.

35. Olfactory Nerve.—The current-strength necessary to stimulate this nerve produces disagreeable central symptoms; such as flashes of light, vertigo, and nausea. For this reason the responses to stimulation of the olfactory nerve are difficult to observe. Ritter describes opening and closing sensations, and also sensations during current-flow. Althaus perceived a phosphorus-like sensation when his olfactory nerve was stimulated with a galvanic current.

In all applications of electricity to the head and neck, special care is necessary to avoid disagreeable accidents. The current should always be turned on gradually through the rheostat, and turned off with the same care and in the same manner. Do not change polarity during flow of current. Gradually reduce the current to zero, and then change the poles. When the current is applied to regions covered with hair, the hair should be thoroughly moistened, to diminish resistance to the current.

VASOMOTOR EFFECTS.

36. The direct current applied to the human organism determines in an incontestable manner, modification in the circulation by increasing its activity. The vasomotor disturbances, always disclosed beneath the electrodes when using a current of moderate intensity, are proofs of this action. Galvanization is

frequently followed by an increase in arterial tension. The hemostatic effects of the direct current are, to a great extent, due to the vasomotor action.

The vasomotor effects beneath the anode and cathode have been known for a long time. When the direct current is applied to the skin in a moderately high density, there appears after a few minutes' duration, a manifest redness at both poles which may last for several hours. If the electric density exceeds that which is permissible to use in electrotherapeutic applications, there appear, in places, circles of a greyish color that soon develop into vesicles.

The vasomotor effects are not the same at both poles. The exact measure of these effects was determined by Bordier by means of a special electrode invented by M. Bergonié. A thermometer was so placed in the interior of the electrode that it registered the variations in the temperature of the skin immediately beneath the electrode. It was found that the local elevation of the temperature due to the vasomotor actions of the current did not have the same value nor act in the same manner at the anode and cathode. The elevation of temperature was always greater at the anode than at the cathode. During the first minute the temperature increases at the anode $\frac{1}{5}°$ centigrade, whereas at the cathode during the same time, the temperature remains normal. These experiments agree with the observations of Erb. For the next few minutes there is a gradual rise of temperature beneath the cathode, which never attains, however, that beneath the anode. At the anode, according to Erb, an intense redness manifests itself almost instantly; the skin turns scarlet; after opening the circuit, the redness remains a long time. At the cathode there is frequently seen, in the beginning of current action, a contraction of the vessels and a pallor of the skin, then a rose color; when the current is broken the skin becomes intensely red and remains so for a long time.

37. Sympathetic and Pneumogastric Nerves.—The action of the direct current on the sympathetic and pneumogastric nerves is very difficult to recognize. In the usual method of operating on the exposed nerves, one nerve is acted upon

by electric stimulus while the other is divided in order to avoid reflexes. If the application is made percutaneously and in physiological conditions, both nerves are acted upon at the same time and it is impossible to separate the reactions of one from those of the other.

According to Rockwell, the current-intensity used is of great importance; a feeble or medium current will often give results opposite to those obtained from a strong current. If in making a percutaneous application of the direct current along the vasculo-nerve trunks in the cervical regions it is not possible to separate reactions of individual nerves, direct-current applications made in this region are of the utmost importance on account of their influence on circulatory and respiratory phenomena.

Beard and Rockwell have made a large number of investigations on patients to determine the actions of electric currents on the sympathetic and pneumogastric. The electrodes were placed one immediately below the mastoid process and the other immediately above the clavicle. They employed a current of 5 to 15 milliamperes for 1 to 10 minutes and arrived at the following conclusions: (1) A slight feeling of drowsiness. This sometimes began to be perceptible shortly after the electrodes were applied, increased up to a certain point, and continued for some little time after the séance was over. In many cases it is not observed until the lapse of 5 or 10 minutes after the séance. This feeling, which was by no means constant, was usually so slight that it might not have been observed had the authors not kept close watch on every sensation produced during the passage of the current, and also for some time afterwards. Some individuals are particularly susceptible to this soporific effect of galvanization of the neck and go completely to sleep during galvanization. Larat remarks that this phenomenon ought to be very rare, as he never observed it. (2) A feeling of warmth throughout the system with sensible perspiration. This was not a constant symptom, although it was often decided. To produce sensible perspiration usually requires a strong current and long applications. This effect was more marked in susceptible and nervous people than in the cold and phlegmatic.

(3) The pulse was sometimes accelerated, but more frequently lowered, two, three, four, or more beats. To determine the effect on the pulse, examinations were made before and after electrization. Every precaution was taken to avoid error by allowing an interval of rest before the sitting, in order to give time for the subsidence of the pulse to its normal condition. In cases of doubt the whole minute was counted, in some instances several times in succession. The patients experimented on were habituated to the use of electrical currents and accepted the applications with the greatest indifference.

38. Beard and Rockwell also made experiments on themselves and on students in order that these conclusions might be free from errors due to emotion. They arrived at the following conclusions:

1.   Both currents—galvanic and faradic—when applied in such way as to traverse the region of the neck in which the pneumogastric and cervical ganglia of the sympathetic are situated, markedly affect the pulse.

2.   The effect is chiefly shown in abruptness of the systole and in abruptness of the diastole, and in shortening of the interval between the cardiac impulse and the arterial impulse. In general it may be said that the force of the pulse is increased. Its rapidity may be either increased or diminished, according to the length of the application and the strength of the current, and analogy would lead us to believe that the effect must widely vary with the individual. The arterial impulse increased probably from the effect on the vasomotor nerves.

3.   The effect of general faradization was to prolong the systole and the interval between the cardiac and arterial impulses. The abruptness of the systole that is so marked during and after faradization through the neck, was not so observed after general faradization. A calming, soporific influence is very frequently produced by general faradization, and the effect in the pulse harmonizes with this observation.

4.   These effects on the pulse gradually pass away, but are distinctly traceable for a number of minutes after the electrodes are removed.

The effect of the current thus applied on the circulation is probably a complex resultant of the effect of electricity on the pneumogastric, the sympathetic, the depressor, and the spinal cord. To differentiate these effects is manifestly impossible.

39. Effect on the Striated and Non-Striated Muscles.—Striated muscles respond in the same manner to both direct and indirect excitation, that is, they contract. The direct muscle stimulation is in reality a stimulation of the intramuscular terminal nerve filaments; therefore, indirect also. Each muscle-fiber receives at least one nerve-fiber, and the stimulation of these nerve-fibers causes contraction when the current is applied directly to the muscle. Muscle-tissue is irritable; that is, it responds to stimulation by contracting when deprived of its nerve-supply. To demonstrate the irritability of a muscle it must be operated on after being deprived of its nerve-supply. Claude Bernard has done this by means of curare, and has demonstrated that muscle-irritability is independent of nerve-fiber. Curare in medium doses does not alter the muscle, but it causes a dissociation of nerve from muscle: it alters the nerve-terminations, the motor end-plates. In this condition, if the nerve is stimulated the muscle remains immobile. Stimulate the muscle directly and it contracts perfectly. Muscular tissue itself, then, responds by contracting when stimulated without regard to nerve-supply. It is not possible, however, in the living human body to excite the muscular tissue directly and alone without the prior production of a pathological condition. The electrical reaction of motor nerves and striated muscles have been carefully studied and the results accurately recorded, thanks to the graphic method employed in physiological investigations.

The effects produced by electric currents on non-striated muscles, the visceral and sensory nerves, are measured by sensations and secondary effects. Non-striated muscles act differently from striated muscles when subjected to the influence of the direct current. Striated muscles contract quickly and energetically, and return at once to a condition of repose when the excitation ceases. When, however, the stomach, the intestines,

or the esophagus and other parts that are composed of non-
striated muscle-fiber are subjected to the electric current, move-
ments are not induced in them until a certain time after the
tissues have been acted upon.   The movement thus produced
continues for some time after the current is withdrawn; it is
wave-like in form, and does not, as in the case of striated
muscles, at once return to its normal condition.   The maxi-
mum of contraction is obtained in non-striated muscles by
means of the direct current regularly interrupted, or by means
of the sinusoidal current of low frequency.

40. Effect of the Current on the Brain.—The effects
of the direct current on the brain depend upon whether the cur-
rent is applied to the denuded brain or whether the current
is applied percutaneously.   The effects of electric excitation
on the denuded brain have been very carefully studied by
Vulpian, Hitzig, Ferrier, and M. François-Franck and Pitres,
and have been described by their graphic method.   These
authors use the galvanic and faradic currents and also con-
denser discharges.   The cerebral region under investigation
was excited by means of a bipolar electrode.   They arrived at
the following conclusions:
   1.   An isolated electric excitation of the cortical gray sub-
stance produced a simple muscular contraction; a series of slow
excitations produced dissociated muscular contractions.
   2.   The same number of electric excitations per second is
required to produce tetanus in the same animal whether the
brain, the motor nerve, or the muscle is acted upon.   By
noting the time that elapsed between the central excitations and
the muscular response and allowing for the latent period of
excitation of muscle and nerve, these investigators calculated
that motor excitations traveled at the rate of 10 meters per
second.   If the white substance beneath the cortical motor
zone is stimulated, muscular contractions are produced exactly
similar to those caused by stimulating the gray matter.   No
effects like these can be produced by the usual percutaneous
application of electric currents.
   The reason for this is clear when we remember the ratio of

the specific conductivity of tissue. The brain is enclosed within bony walls and the resistance of bone is twenty times greater than that of muscle and ten times greater than nerve. If a current of 10 milliamperes is applied percutaneously, the current that reaches the brain is extremely feeble, a fraction of 1 milliampere. When, therefore, electric energy is indicated in the treatment of cerebral diseases, to apply the energy, it is necessary to reduce the resistance of the skin by using large electrodes thoroughly saturated with warm water and at the same time to increase the current-intensity. The current-intensity should be increased very gradually and returned to zero in the same manner. Current-intensities varying from 40 to 50 milliamperes have been applied percutaneously to the brain in this manner with very favorable results. In the percutaneous application of the direct current, or any electric current to the brain, it should not be forgotten that nerve-trunks and blood-vessels penetrate the bony walls of the brain and that these nerves and vessels are comparatively good conductors of electric currents.

41. When a direct current is passed transversely through the brain, the electrodes being placed on the mastoid processes, the current divides into a large number of lines of flux, the major part of which encircle the cranial vault, conducted by the extracranial soft tissue. Very few of the flux lines penetrate the cranial walls. Per unit of surface the intensity in the interior of the cranium is twenty times less than in the extracranial soft tissues. If, however, a feeble current is passed transversely through the brain from one mastoid process to the other, very decided dizziness is perceived, which continues during the passage of the current. During the passage of the current there is a marked tendency to lean toward the positive pole while objects in view seem to move in the same direction. When one electrode is placed on the forehead and the other on the occiput, the ratio of extracranial and intracranial current-intensity per unit of surface is the same with the same current-strength as when the current is passed transversely through the brain. When, however, the

current is passed in a longitudinal direction, it is accompanied by little if any tendency to vertigo. This is an important fact and should always be thought of when an electrical application to the cerebrum is indicated.

Confusion of thought, occipital headache, and nausea or vomiting sometimes follow the attempts at brain galvanization. Very strong currents have caused fainting and convulsions.

Lowenberg states that brain galvanization causes contraction of the vessels in the cathodic area and dilatation in the anodic area. These statements, however, have not been confirmed by other observers.

42. Effect of the Current on the Spinal Cord.—The direct current applied to the spine, with the anode at the nape of the neck and the cathode over the lumbar vertebræ, will sometimes cause contraction in the thigh muscles as well as pricking, scalding sensations in the legs. The effects produced by electric currents applied to the spinal cord depend on whether the application is direct (on the denuded cord) or indirect (through the skin and bony canal). Rigid cramp of all the muscles of the trunk and extremities follow electrization of the spinal cord when an electrode is placed at either extremity of the denuded cord.

If the spinal cord be divided about its center and the lower half electrized, the muscles of the lower or hinder limbs will contract. If the upper half be electrized the muscles of the forelimbs will contract. The spinal cord substance is therefore susceptible of direct-current stimulation.

In making electrical applications to the spinal region, percutaneously, with a view of influencing the spinal cord, it should be remembered that the cord is enclosed in a bony canal, and that in order to cause a few milliamperes to traverse the spinal cord it is necessary to use large electrodes thoroughly saturated with warm water and employ a current intensity of at least 50 milliamperes. The small hand electrode, using 10 or 15 milliamperes, is wholly inadequate.

The possibility of the direct current influencing the central

nervous system (brain and spinal cord) was for a long time denied. Through the experiments of Erb, Bettelheim, Burckhardt, and von Ziemssen, we are now, however, certain that when we apply the direct current in the usual therapeutic methods to the central nervous system, part of the current, in obedience to the law of derived circuits, penetrates the bony walls of the cerebrospinal axis and passes through the tissues of the brain and the cord. If the brain or spinal cord is exposed and a direct current applied to it following the usual percutaneous method, part of this current can be obtained in a derived circuit formed by a galvanometer and two conducting-wires, the terminals of which are inserted in the substance of either the brain or spinal cord. Changing the direction of the principal current will change the direction of the derived current.

ELECTRODIAGNOSIS.

43. Electric currents are frequently resorted to as an aid in diagnosing certain pathological conditions and in determining important conclusions as to the probable duration and gravity of those conditions. Until quite recently the use of electric currents in diagnosis and prognosis was limited to diseases of the nervous system. In 1879, Vigouroux introduced into electrodiagnosis the measurement of the electric resistance between different surfaces of the body. It appears established that the resistance between two electrodes placed on two different surfaces of the body is sometimes increased and sometimes diminished by the existence of certain pathological conditions. Charcot regarded the diminution of electric resistance of the body as an important symptom of exophthalmic goiter.

The use of electric currents as an aid in diagnosis in gynecology is due to Apostoli. According to him a uterus that supports a direct current of from 100 to 150 milliamperes without reaction either during the operation or after it has healthy adnexa. We shall, therefore, consider electric currents (1) in the diagnosis and prognosis of diseases of the nervous system; (2) in diagnosis based on the variations of the electric resistance of the tissues; (3) in diagnosis in gynecology.

DISEASES OF THE NERVOUS SYSTEM.

44. Fundamental Principles.—In diseases of the nervous system, electrodiagnosis is based on the abnormal electric reactions of nerves and muscles, the physiological reaction of which has been described; every reaction of nerve and muscle that departs from these is pathologic. The electric examination of nerve and muscle permits us to draw important conclusions on the probable duration of a disease, on its gravity and prognosis.

The principal point in the technique of this method is to localize the current on the part under examination, and to avoid as much as possible the excitation of neighboring nerves and muscles. Whether we are using the galvanic or faradic current in exploring nerves and muscles, the important point is to locate the current on the nerve or muscle under examination in order to prevent the confusion that would certainly arise from contractions of neighboring muscles should they be stimulated by current diffusion.

45. Methods of Exploring Nerves and Muscles. There are two methods of exploring muscles, namely, *monopolar* and *bipolar*. The monopolar method was proposed by Erb and the bipolar method by Duchenne. In using the galvanic current in exploring nerves and muscles the unipolar method is to be preferred on account of the differentiation required in polarity. The electrodes must be widely separated in making galvanic tests in order to differentiate polar actions. In the method of Erb one electrode is large, the other is small and is placed on the motor point of the muscle under observation.

The voltage of the galvanic current used in electrodiagnosis is low, twenty-five volts at most, and there is therefore very little current diffusion, the contraction being limited to the muscle under examination. For the faradic current the conditions are changed; the voltage is a great deal higher and the current diffusion is consequently greater. High voltage may be said to mean current diffusion. In order therefore to limit the faradic stimulation to an individual muscle the bipolar method

of Duchenne should be employed. Duchenne used two small pads of equal dimensions as electrodes and placed them a short distance from each other on the muscle under examination. This is the only means of obtaining absolute precision in electrofaradic exploration. It was by this means that Duchenne was enabled to accomplish his great work in "Localized Electrization."

46. Apparatus Necessary.—For making electrical tests of nerves and muscles a good physician's induction-coil and a direct current, either from a battery or dynamo, capable of maintaining a strength of current in the patient's circuit of at least 20 milliamperes will be required. Both the induction-coil and the direct-current apparatus must have some means of modifying the strength of the current (rheostat). The direct current must be provided with a pole-changer in the patient's circuit and a milliammeter for registering the strength of the current used; so far no convenient or practical milliammeter for measuring the currents of the induction-coil has been devised. The conducting-cords should be perfect and the active electrode, the one used to apply the current to the nerve or muscle to be tested, should be a break-circuit electrode so that the current may be interrupted at the will of the examiner without any other change being made in the conditions.

47. Technique.—The patient should be so placed that the light falls directly upon him and the milliammeter scale, and he should be as easily accessible from one side as from the other. He should be instructed to take a comfortable posture and the muscle under examination should be relaxed. In the case of adults this will be readily obeyed, but with children there will be some difficulty. With children it is necessary to act with gentleness and perseverance. In many cases, to obtain precise results in cases of children it will be necessary to administer an anesthetic.

When the hands, arms, and face are to be examined, the patient is best seated on a chair with a high back and he should lie down when other parts of the body are to be examined. When the patient is in a sitting posture, the indifferent

electrode of 100 square centimeters, well moistened with warm water, is placed on the back below the neck. In this position, when the patient leans back, a good contact is established between the electrode and his skin.

When the patient is in the recumbent posture, the indifferent electrode may be placed on the back or abdomen as conditions require. The electrode is then connected by means of a rheophore to the binding-post of the electric source. The active electrode, with an interrupting device in its handle, is also thoroughly moistened and applied as accurately as possible to the motor point of the nerve or muscle under examination.

48. Faradic Current. – The examination is always begun by testing faradic irritability. There is but one reason why faradic currents are used first in neuromuscular explorations, and that reason is of capital importance. When the faradic current is used first in electrodiagnosis it very frequently renders unnecessary the more complicated galvanic explorations. If muscles respond in a normal manner to faradic stimulation, we may be sure that they will also respond in a normal manner to galvanic stimulus. It is very important to have this clearly fixed in the mind of the student, as it is one of the most important facts in electrodiagnosis and one of the distinctive features in the so-called reaction of degeneration.

The current from the coarse or medium coil is always used, and the slow interrupter is adjusted to about 60 interruptions · per minute. The faradic examination is conducted in the following manner: The active electrode is placed on the motor point, nerve, or muscle; the rheostat at the beginning of the examination is at its maximum of resistance; the resistance in the rheostat is reduced little by little until the patient experiences a slight sensation due to the faradic current. On reducing the resistance in the rheostat still more a contraction is produced. The minimal contraction having been obtained, the quantity of current necessary for its production should be noted, and at the same time attention should be given to the quality of the contraction in order to determine if there is any deviation from the normal.

49. Direct Current.—By means of a switch the patient is now placed in the direct-current circuit. The most important consideration in the direct-current examination of motor nerves and muscles is polarity. The direct-current examination is more complex than the faradic, and the responses obtained by it in various pathological conditions have greater diagnostic and prognostic significance. With the faradic current polarity is not considered; with the galvanic current the dissociation of polarity is an essential part of the examination.

Place the active electrode, negative, on the motor point and gradually reduce the resistance in the rheostat and at the same time close the circuit, at short intervals, by means of a device in the handle of the electrode. At one of these closures a contraction will appear. This contraction is short, sharp, and well-defined, and as it occurs on closing the circuit with the cathode it is called *cathodic closing contraction*. The intensity of the current required to produce the contraction is also noted, and if it should be 2 milliamperes the results obtained are thus expressed: $C\,C_1 = 2$ milliamperes.

Now, the circuit being kept broken by means of the interrupter, but with the testing electrode still on the motor point, the polarity of the current is changed and the active electrode is made positive. Reduce the current to zero and proceed as before, reducing the resistance in the rheostat and closing the current at short intervals until a contraction appears—*anodic closing contraction*. While the circuit is closed, again read the milliammeter. It may now read 3 milliamperes and is recorded thus: $A\,C_1 = 3$ milliamperes. In closing with the cathode, 2 milliamperes were required to produce a contraction; the cathodic closing contraction is therefore stronger than the anodic closing contraction and the fact is noted $C\,C_1 > A\,C_1$.

With the electrode on the same motor point the current is now kept closed and the current-strength gradually increased, while the circuit is opened at intervals until a contraction appears. The milliammeter may indicate 5 milliamperes and the result is noted $A\,O = 5$ milliamperes. Anodic closing requiring only 3 milliamperes, therefore anodic closing stimulus

is stronger than the opening stimulus; that is $A\ C_1 > A\ O$. In the case of some nerves, $A\ O$ is stronger than $A\ C_1$ and sometimes they are equal.

With the circuit broken, reduce the current to zero and again change polarity, making the testing electrode negative. Now increase the current-strength to about 10 milliamperes and break the current by means of the handle in the electrode. A contraction may appear. This takes place at the cathode and on opening it is recorded $C\ O = 10$ milliamperes. Here the operator should be careful not to close the circuit until the current is again reduced to zero on account of the energetic contraction that would be caused by $C\ C_1$.

In every electrical examination there is a limit beyond which the intensity of the current should not be pushed. With an active electrode of 3 square centimeters, and a current of 5 milliamperes, the process becomes painful and serves no useful purpose.

It has now been determined that the normal muscle responds to galvanic and faradic currents by a sharp contraction, and that with the galvanic current the muscle responds in four different ways, which may be formulated as follows: $C\ C_1 > A\ C_1 > A\ O > C\ O$. It may be laid down as an axiom in testing neuromuscular excitability that abnormal reactions are always connected with alteration in the organ examined.

50. Summary.—The important factors in the technique of electrodiagnosis of diseases of the nervous system are: (a) The apparatus used should be in good working order and both electrodes should be thoroughly saturated with warm water. (b) Place the patient in a comfortable position and in a good light so that the region under examination as well as the scale of the milliammeter are easily observed. (c) The muscle under examination should be relaxed. (d) In testing for faradic irritability, if there is difficulty in localizing the current on the muscle under examination, use the bipolar method of Duchenne. (e) Always begin the examination with the faradic current. (f) The main factor in examinations with the galvanic current is dissociation of polarity; therefore, the

monopolar method of Erb is always employed. (*g*) Find the
motor point. (*h*) Detect the minimal contraction. (*i*) Observe
the form of contraction. (*j*) With a thoroughly moistened
testing electrode, pressure is for the most part unnecessary:
contact is all that is required.

PATHOLOGICAL MODIFICATIONS OF NEUROMUSCULAR REACTIONS.

51. Anatomy and Physiology of Motor Paths.—In
order to make the pathological modifications of neuromuscular
reactions easier to understand, we shall state briefly a few funda-
mental facts in the anatomy and physiology of the motor paths.
According to the doctrine of neurons (Waldeyer, 1891), the
entire nervous system is composed of innumerable non-continu-
ous units. These units are called **neurons,** and each neuron
consists of a ganglion cell with its processes. These processes
are of two kinds: (1) The protoplasmic processes or dendrons,
constituting an integral part of the cell; (2) the axon, neuraxon,
or axis process. There is usually only one axis process to a
cell, but sometimes two. The axon, neuraxon, or axis process
is the chief process.

In the motor region of the cerebrum are the so-called pyram-
idal cells. The protoplasmic processes of these cells are
directed toward the cortex and the axons or long processes
course downwards toward the periphery. They pass through
the white substance of the hemispheres, through the posterior
segment of the internal capsule, through the crus, the pons,
and the medulla oblongata. Ninety per cent. of these axons
cross over at the lowest point of the medulla, each one decus-
sating with the symmetric fiber of the opposite side. The
crossed bundle forms the anterior pyramids and passes into the
lateral columns of the spinal cord to form the crossed pyramidal
tract. At different levels of the spinal cord, according to whether
they are to convey impulses to the muscles of the arms or of the
legs, fibers take a horizontal course and pass into the anterior
horn, where they split up into their arboreal endings. These
arboreal endings, or end brushes, surround the large polygonal

cells in the anterior horn and enter into connection with them
by contact.   Each pyramidal cell with its processes is desig-
nated a *central motor neuron*.

52. The polygonal cell of the anterior horn gives off
numerous short processes, which have centripetal conduction,
and a single long process or neuraxon, which conducts to the
periphery.   The neuraxon passes through the anterior horn to
the anterior root as a fiber of the root and then as a fiber of the
peripheral motor nerve reaches a muscle-fiber.   When it reaches
the muscle-fiber, it splits up into terminal brushes and enters
into connection with the muscle-fiber by means of contact; this
polygonal cell of the anterior horn with its processes is desig-
nated a *peripheral motor neuron*.   The motor path of the cranial
nerves is constituted in the same manner, consisting also of two
neurons.   The central motor neuron has its cell in the cortex
and its neuraxon, and its end brush, which enter into connec-
tion with a cell of the nucleus of the cranial nerve of the oppo-
site side.   With this cell begins the peripheral motor neuron of
the cranial nerve.   The neuraxon of this cell runs as a fiber to
the base of the brain and then as a cranial nerve-fiber to the
muscle-fiber.   It connects with the muscle-fiber by means of
its end brush as described.

From these facts, it is evident that the cell of the cranial
nucleus has the same physiological significance for this cranial
nerve as has the polygonal cell of the anterior horn for its spinal
nerve.   Each neuron constitutes an embryologic and histologic
unit and acts physiologically as a unit.

When one of the two neurons that constitute the motor path
is injured or diseased so that its continuity is broken, or if the
cell belonging to one of the neurons is injured or diseased, the
neuraxon of the injured or diseased neuron undergoes degener-
ative changes.   These degenerative changes take place only in
the neuron in which the disease is located; the remainder of the
motor path remains intact.   When the peripheral motor neuron
degenerates, the muscle-fiber to which it is connected by contact
degenerates also.   As each neuron is an independent unit, the
degeneration caused by disease or injury is limited to the neuron

so affected. Muscle-fiber virtually forms a part of the peripheral motor neuron, and when the neuron degenerates, the muscle-fiber degenerates with it. In lesions of the central motor neuron the muscle-fiber is not so affected.

53. Reaction of Degeneration.—The electrical reactions of degenerated muscles differ from the reactions of a healthy muscle and from a muscle that has undergone simple atrophy; muscular degeneration can therefore be recognized by means of electric investigation. The electrical reaction of degenerate muscles is designated reaction of degeneration, or simply *R D*.

R D is present only when the peripheral motor neuron is diseased or injured. It is not present in disease or injury of the central motor neuron, or in disease of the muscles, or in diseases of other parts of the nervous system or the body. When *R D* is present it is a sign that a diseased process is going on in the peripheral motor neuron. Other pathological modifications of the normal neuromuscular reactions are due to disease of other parts of the motor tract.

Duchenne observed that certain pathological conditions determined modifications in the manner in which muscles reacted to the faradic current. He analyzed with an admirable method a multitude of pathological conditions and, so far as the faradic current is concerned, left little for his successors to accomplish. Remak and Benedikt undertook to do for the galvanic current what Duchenne did for the faradic current. Erb discovered the reactions of degeneration. In these reactions Erb noted not only quantitative changes in neuromuscular irritability but also qualitative changes in the order and form of muscular contractions; he established the value that these reactions could have in the diagnosis and prognosis of certain diseases. It has been pointed out by Doumer that the many forms of abnormal electrical reactions which have been described (reaction of degeneration, myotonic reaction, reaction of compression, reaction of diathesis of contraction, reaction of exhaustion) are really groups of elementary, or simple, reactions, each of the latter being most frequently independent of one another, and each having its own pathological significance.

54. Reaction of Erb.—The reaction of degeneration as described by Erb is constituted by two orders of phenomena, which have their location in the muscles corresponding to the neuron lesion.

1. Constant fundamental phenomenon: absolute abolition of faradic contractility, no matter what intensity of excitation is employed.

2. Phenomena that are accessory and variable according to the age and gravity of the neuron lesion: contradictory galvanic reaction, that is, sometimes increased, sometimes decreased, and it may be abolished; and at the same time there are qualitative changes, the anode taking the place of the cathode and the muscular contraction becoming lazy, sluggish, and prolonged.

The fundamental phenomenon of RD described by Erb is, so far as muscle examination is concerned, complete absence of faradic contractility. The galvanic responses are somewhat complex. If, however, the muscle reactions of the galvanic current are complex, they are also of great importance because they correspond to fixed periods of RD, and are therefore of great value in prognosis. Mild RD, medium RD, and grave RD, manifest themselves by different galvanic reactions, it is true, but the reactions are always the same for each of these cases, and always having for constant substratum the complete abolition of faradic contractility.

The quantitative modifications of muscular reactions for the galvanic current are easily detected. A superficial examination shows that a feeble current contracts the degenerated muscle while the healthy muscle remains quiet. The same is true when the galvanic contractility is decreased: it will require a much stronger current in this case to produce a muscular contraction.

The qualitative investigations of muscle reactions require more practice. In normal nerve and muscle, negative closing contraction is the strongest. In the beginning of a case of mild RD the negative contraction is still the strongest, but as the degeneration advances, the positive closing contraction equals the negative closing contraction and may be expressed thus $AC_1 -- CC_1$. In a more advanced stage AC_1 is greater than CC_1. The same phenomenon occurs in the opening contractions, that

is the negative opening contraction becomes stronger than the positive opening contraction. The formula for $R\,D$ is then $A\,C_1 > C\,C_1 > C\,O > A\,O$. While the order of the polar formula is being determined the form of the contraction should be carefully observed. The form of the muscle contraction will be sluggish and prolonged.

55. Difference in Reactions Caused by Faradic and Galvanic Currents.—A very important question that might be asked is as follows: Why does a muscle in a condition of $R\,D$ respond almost always to the galvanic current, whereas it does not react at all to the slowly or rapidly interrupted faradic current or to static sparks. The answer to this question has been given by Boudet and d'Arsonval as follows: In $R\,D$, muscular contractions are produced with the faradic current after the faradic wave has been lengthened by placing a condenser in circuit. The explanation is therefore a question of physics. The degenerated muscle requires for its contraction a current of duration longer than $\frac{1}{10}$ second. The ordinary faradic current impulse has a shorter duration than $\frac{1}{10}$ second, and it does not seem to have the time to stimulate the contractile elements of a muscle whose contractility is lessened by the fact of its degeneration. Simply increase the duration of the faradic flux by placing between the terminals of the coil a condenser of sufficient capacity; the increased wave-length of the faradic current will now contract the degenerated muscle with the same ease and energy as the galvanic current. The inverse is also true. If, by means of a rapid commutator placed in the galvanic circuit, the galvanic variations are made of short duration, they will no longer produce contractions of the degenerate muscle.

The reactions of the motor nerves, the real cause of the phenomena of $R\,D$, are simple. The motor nerve in $R\,D$ does not respond to electrical stimulus. The irritability of the motor nerve to the galvanic and faradic current is lost. As this absence of reaction of motor nerves in $R\,D$ is constant and the same in all stages of established $R\,D$, it can have no prognostic significance: it simply signifies that $R\,D$ is present, nothing more.

56. Summary.—The ensemble of the reactions described by Erb and known as reaction of degeneration may be briefly stated as follows:

1.   Abolition of faradic excitability in nerve and muscle.

2.   Abolition of galvanic excitability in nerve.

3.   Exaggeration of galvanic excitability in muscle, and in more advanced stages decreased galvanic excitability.

4.   Inversion of the normal polar formula, CC_1 becomes less than AC_1.

5.   Sluggish contractions.   Of all the signs that constitute RD, the most important and necessary is the sluggish contraction.

To this typical RD, as described by Erb and as we see it occurring after severe traumatism, there are many exceptions, the most important of which are: (1) The irritability of the nerve is simply diminished while the muscle reacts to the galvanic current as in typical RD, that is, with increased excitability, sluggish contraction, and inversion of the polar formula.   (2) The irritability of nerve and muscle may be simply diminished for coil-currents while the muscle reacts to the galvanic current with a sluggish contraction and without inversion of the polar formula.   (3) The muscle may respond by a sluggish contraction to stimulation applied through the nerve-trunk.   (4) The muscles may respond in a sluggish manner to coil-currents applied through the muscle itself.

Doumer resolved these groups of reactions into the elementary reactions of which they are composed.

These elementary, individual, abnormal reactions are:

1.   For the faradic current: (a) increased irritability; (b) decreased irritability; (c) inexcitability.

2.   For the galvanic current: (a) increased irritability; (b) decreased irritability; (c) inexcitability; (d) variations in the relative values of CC_1 and AC_1 (reaction of Erb); (e) variations in the relative values of CC_1 and CO (reaction of Rich); (f) longitudinal reaction.

3.   Abnormalities in the character of the muscular contraction: (a) diminution of lost time; (b) increase of lost time; (c) diminution in duration of contraction; (d) increase in

duration of contraction; (*e*) alterations in the form of the curve; (*f*) reaction of exhaustion.

These abnormal elementary electrical reactions may be arranged in two groups: (1) Quantitative modifications. (2) Qualitative modifications.

Quantitative Modifica- tions Are
{
Increased excitability to galvanic and faradic currents;

Decreased excitability to galvanic and f :adi currents;

Inexcitability.
}

Qualitative Modifica- tions Are
{
Variations in the relative energy of the contractions produced by the galvanic current;

Longitudinal reactions;

Variations in the form of the contraction curve.
}

57. Quantitative Modifications. — Duchenne utilized the variations of faradic excitability of nerve and muscle to determine their anatomic state, to locate lesions, and to establish a prognosis in different diseases. The irritability of a motor nerve or muscle is increased when the minimal contraction is produced by a weaker current than that required to produce the minimal contraction in their normal state. Their irritability is decreased when a stronger current is required to produce the minimal contraction that is required in the normal state. In marked cases of increased irritability the galvanic reactions are very interesting. $C C_1$ contraction is produced by a fraction of a milliampere, and the $C O$ contraction by a strength of current that would, in the normal state, hardly produce $C C_1$ contraction. With a current a little stronger, $A C_1 T_e$ and $A O T_e$, T_e meaning tetanus, are produced, and also $C O T_e$, as in a case reported by Cohen.

In these cases of increased irritability there are no qualitative changes, the polar formula is normal and the contraction lightning-like, as in health. Simple increased irritability is almost a pathognomonic sign of tetany. The irritability is increased for both currents, very seldom for the galvanic current alone. The presence of increased irritability makes it possible in difficult cases to diagnose between true tetany and certain hysterical conditions. In these hysterical conditions the irritability is

not, as a rule, increased.   The diagnosis of tetany in children
is absolutely certain when with the active electrode on a nerve,
the median for example, $C\,C_1$ contraction is produced by .7 milli-
ampere and $C\,O$ by .5 milliampere.   Cerebral paralysis (recent
or marked spastic hemiplegia), the first stage of locomotor
ataxia, and some cases of peripheral paralysis have increased
irritability without qualitative changes.

58.   Reaction of Duchenne. — Decreased   irritability
is much more frequent than the increased variety.   Irrita-
bility may be decreased for both currents or for one of
them.   It is most frequently decreased for both.   The
normal polar formula and the form of the contractions are
unchanged.   Simple decrease of irritability is found in a large
number of diseases.   In muscular atrophies due to joint
lesions, if these atrophies exhibit qualitative changes, there is
some complication present, as neuritis.   In atrophies due to
cerebral lesions, lesions of central motor neurons, in apoplexy,
central softening with monoplegia, hemiplegia, or diplegia; the
changes of irritability are purely quantitative in these conditions
and generally the irritability is decreased.   There are no quali-
tative alterations of muscular contraction.   There is also found
decreased irritability in other diseases of the central motor
neuron when the peripheral neuron is intact, and in diseases of
the white substance of the spinal cord, spastic spinal paralysis,
multiple sclerosis, in hemorrhage, and softening without partici-
pation of the anterior horns, in disease of the crura cerebri,
pons, and medulla oblongata (without participation of the
nuclei of the cranial motor nerves).   The irritability in these
diseases is either normal or decreased, and generally for both
currents.   The irritability is decreased in certain cases of tabes
and in functional neuroses, particularly in hysteria.   The elec-
tric examination is important in cases of traumatic hysteria.
A positive demonstration of decreased irritability will exclude
shamming.

Is a progressive atrophy spinal or muscular in origin?   Elec-
trical reactions will determine this.   In atrophies of muscular
origin there are no electrical changes, simply a diminution of

irritability. In those of the spinal form there is reaction of degeneration.

Quantitative changes of neuromuscular irritability do not determine the location of the lesion. They signify that there is alteration at the point of examination or peripheral to it. This alteration may be in the nerve or in the muscle or in both. Qualitative changes signify that the disease or injury is in the nerve.

59. Partial Reaction of Degeneration.—There is diminished irritability for both currents in nerve and muscle toward the end of the first week. In the next week the irritability of the nerve and faradic irritability of the muscle are preserved, but show a decrease. Frequently they remain quite normal. On the contrary the muscle reactions for the galvanic current have all the characteristics of $R\,D$: sluggish contraction, increased irritability, and inversion of the normal polar formula. In a few weeks—at most 8 or 12 weeks—the reactions return again to normal. Sometimes partial $R\,D$ runs a more unfavorable course and may last for years. This occurs quite frequently in progressive diseases, as in syringomyelia. The irritability of the motor nerve may become very much decreased, also faradic irritability of the muscle. The galvanic irritability of the muscle may be normal or below normal, while the contraction preserves its sluggish character.

60. Reaction of Rich.—This reaction is based on the relative variations of $C\,C_1$ and $C\,O$. Normally, these two contractions occupy the extremes of the polar formula, that is between them is found $A\,C_1$ and $A\,O$. When the reaction of Rich is present it is altogether different, the contraction $C\,C_1$ and $C\,O$ tend to equal each other. The current required to produce $C\,O$ in the normal state may be 10 times stronger than that required to produce $C\,C_1$; whereas in the reaction of Rich it will require 1.75 milliamperes for $C\,O$ and 1.25 milliamperes for $C\,C_1$.

This reaction might be called the reaction of compression, as it is usually found in the muscles when the nerve that supplies them has been compressed. The changes in the nerve are probably due to insufficient blood-supply. The reaction of Erb is based on the relative variations of $C\,C_1$ and $A\,C_1$.

of importance, as it enables one to diagnose a contracture about to appear and to fix the time when sclerosis of the lateral columns actually begin.

2. *Paralytic Type.*—This is characterized by (*a*) prolongation of lost time, (*b*) diminution in height of curve. The paralytic type is found in all cases of paralysis when the muscular tissue is intact, but when the nerve centers are involved. The excitation arrives later than normally within the muscular tissue and is less energetic in its action.

3. *Atrophic Type of Curve.*—This is characterized by (*a*) increase of lost time, (*b*) increase of duration of contraction, (*c*) slow ascent, (*d*) slow descent, (*e*) diminished amplitude. The atrophic type of curve is always found in simple atrophy of muscles.

4. *Degeneration Type of Curve.*—This type has the same characteristics as the atrophic, with this difference, however, that it presents undulations in the line of descent. The degeneration type of curve is found in all cases of muscular atrophy in which the corresponding nerves are degenerated.

64. Semeiology.—When electromuscular contractions depart in a notable manner from the physiological type, it means that there is pathological trouble in the muscle or nerve or in the central nervous system. Sometimes the irritability is increased, sometimes diminished, and at times is abolished. In other cases there are qualitative changes of the electromuscular reactions, the so-called reaction of degeneration. Each of these modifications corresponds to different lesions, so that electrical exploration of muscles or nerves becomes an element in diagnosis. Simple increase of irritability without *R D* is usually accompanied by exaggerated reflexes with the exception of beginning tabes. The increased electric irritability is much more constant than exaggerated reflexes. Simple diminution of irritability without *R D* is a symptom that is frequently observed. Great care should be observed in interpreting diminished irritability. The sound and healthy sides should be carefully compared with each other.

The detection of the minimal contraction is sometimes

difficult, and the beginner in electrodiagnostic work may easily make a mistake. The electrode must be placed on the motor point and should be thoroughly moistened. It must also be remembered that even in healthy individuals there is sometimes a difference in the electric irritability of symmetrical parts of the body.

When $R\,D$ is present, it permits us to affirm that the lesion which causes the paralysis is in the peripheral motor neuron. The lesion is in the gray matter of the anterior horns of the spinal cord, in the motor nerves, or in the terminal ramifications of the motor nerve. The muscle-fiber is always secondarily attacked. The presence of $R\,D$ permits us to affirm that the muscle is undergoing granular degeneration and that the cause of this degeneration is not in the white substance of the cerebrospinal axis. *The peripheral motor neuron, either spinal or cranial, is diseased or injured.*

Cerebral diseases or myopathic atrophies are not accompanied by $R\,D$. In order to determine which part of the peripheral motor neuron is affected, sensibility, reflexes, and the history must be investigated. There are cases in which $R\,D$ suffices in itself to establish the diagnosis. If we detect $R\,D$ in an extremity of a child, the diagnosis is infantile paralysis. It is not cerebral, because $R\,D$ does not accompany cerebral paralysis. Toxic neuritis in children is usually bilateral. If we add the sudden appearance of the paralysis, the diagnosis is absolutely certain.

In the case of facial paralysis with $R\,D$ we can affirm the peripheral origin of the disease. Facial paralysis of central origin never exhibits $R\,D$. In progressive muscular atrophies the presence of $R\,D$ differentiates myelopathic from myopathic atrophies.

65. Reaction of Degeneration in Prognosis.—With regard to prognosis $R\,D$ may be divided into several stages as follows:

1. Abolition of faradic contractility.   Exaggeration of galvanic contractility.

2. Abolition of faradic contractility.   Exaggeration of

galvanic contractility with commencing inversion of the normal polar formula: $C\,C_1 > A\,C_1 > A\,O > C\,O$.

3. Abolition of faradic contractility. Decreased galvanic contractility with complete inversion of the normal polar formula: $A\,C_1 > C\,C_1 > C\,O > A\,O$.

4. Complete abolition of all contractility.

The value of $R\,D$ in prognosis depends on the fact that the different stages of $R\,D$ have known histological changes of nerve and muscle structure, so that when we have determined the degree of severity of $R\,D$, we can also determine the existence of the histological changes that have already taken place in the nerve and muscles involved. The value of $R\,D$ in prognosis is subordinated to the anatomic cause of the disease. $R\,D$ in rheumatic facial paralysis may be exactly similar to $R\,D$ in infantile paralysis, yet the prognosis in these two diseases is entirely different. The lesion in rheumatic facial paralysis (peripheral neuritis) is curable, whereas the lesion in infantile paralysis (destruction of ganglion cells of peripheral motor neurons) is irreparable. It is evident, therefore, that $R\,D$ of rheumatic facial paralysis cannot be compared with $R\,D$ of infantile paralysis; but $R\,D$ of one case of rheumatic facial paralysis can be compared with $R\,D$ of other cases of rheumatic facial paralysis, and the prognosis can be established.

If the patient comes to us on the second or third day of an attack of rheumatic facial paralysis and we find the electrical reactions normal, the paralysis will disappear in 3 or 4 days; if he comes to us on the seventh or eighth day and the reactions are still normal, we may affirm with great probability that complete $R\,D$ will not develop. Partial $R\,D$ or qualitative changes may develop, or normal reactions may continue. If on the seventh or eighth day we observe a decrease of irritability, direct or indirect, or both, it is still possible that the disease will advance no further, yet it may be the beginning of partial or complete $R\,D$.

In the second week, or at the latest in the third week, the prognosis can as a rule be established. If at this time sluggish contraction is observed, $R\,D$ is certain. With the sluggish contraction will also be observed increased galvanomuscular

irritability and frequently beginning inversion of the normal polar formula. At the same time, or a little later, it can also be decided whether the $R\,D$ is partial or complete. If nerve irritability disappears for both currents and faradic irritability for muscles, the $R\,D$ is complete. If these reactions do not disappear, $R\,D$ is produced whether nerve irritability for both currents and faradic irritability for muscles is increased or diminished. If partial $R\,D$ is present, the paralysis will last from 6 to 12 weeks; if complete $R\,D$ is present the disease will last, as a rule, from 6 to 9 months, or it may perhaps be incurable.

If about the fifteenth or twentieth week in those severe cases of $R\,D$ it is possible to produce even slight muscular contractions by stimulating the nerve even with strong currents, or if the muscle can be made to react by direct applications of a strong faradic current, it is probable that we have to do with a curable form of facial paralysis. If about this time the sluggish contractions become somewhat quicker, the prognosis is in general favorable. When the galvanomuscular irritability goes on decreasing with persisting sluggish contractions, the prognosis is unfavorable.

66. It is always better to wait a long time before giving an absolutely unfavorable prognosis. In the thirtieth or fortieth week, even in a year or later, there may be a return of neuromuscular irritability and normal neuromuscular reactions. $R\,D$ has special prognostic significance in individual cases of peripheral paralysis, as rheumatic facial paralysis, and individual cases of pressure paralysis as radial paralysis, etc. The majority of paralyses of this kind are curable and can be divided into three groups: (1) Paralysis without $R\,D$, recovery in from 2 to 3 weeks; (2) paralysis with partial $R\,D$, recovery in from 6 to 12 weeks; (3) paralysis with complete $R\,D$, recovery (if curable) in from 6 to 12 months.

In all these cases we can at the end of the second week, as a rule, make a definite prognosis. If the case belongs to the first class, recovery takes place in 2 or 3 weeks; if the second, in 6 to 12 weeks; and if to the third (and the case be curable), in 9 to 12 weeks. Most of the cases of spinal and bulbar paralyses

and of traumatic and rheumatic lesions of peripheral nerves can be classified in the above groups, and electromuscular reactions will be a considerable help both in diagnosis and prognosis.

In individual cases, particularly in neuritis of the infective or toxic type, electrical reactions may be of little or no value in prognosis. In these cases the electrical reactions inform us of the condition of nerve and muscle at the time of the examination and nothing more. The future progress of the case will depend on whether the poison or infection has ceased its work. In this respect we must be particularly cautious in diphtheritic paralysis and alcoholic paralysis. In diphtheritic paralysis the alteration in electrical reaction may be simply quantitative, but the toxin may be continuing its work and $R\,D$ will appear later. The alcoholic may stop for a time his drinking habit and there will be no $R\,D$; he recommences to drink and there will be a return of sluggish muscular contractions with all the phenomena of complete $R\,D$.

ELECTRODIAGNOSIS IN GYNECOLOGY.

67. The galvanic and faradic currents sometimes render important service in the diagnosis of certain pathological conditions of the uterus and its adnexæ. It is often necessary in a given case, before deciding whether treatment should be conservative or radical, to ascertain the condition of the adnexæ, whether they are healthy or diseased and to what degree. For this purpose exploratory cœliotomy is the usual procedure. In this class of cases electric currents are capable of rendering important services. They can clear up a doubtful diagnosis and thus prevent surgical interference or establish with certainty the necessity of such interference.

68. Faradic Current.—The application of this current will decide the real nature of ovarian pain. If the pain is purely hysterical the faradic current will relieve it. If the faradic current does not relieve the ovarian pain, the pain is due to some other cause, and galvanic applications will be required in addition to the faradic, or surgical intervention may become necessary.

69. Galvanic Current.—Intra-uterine applications of the galvanic current will inform us as to the integrity or non-integrity of the uterine adnexæ. The intra-uterine sensibility of the direct current is dependent on the sensibility of the uterine adnexæ, and the electrical reactions obtained from an intra-uterine application will decide whether the adnexæ are inflamed or not. The clinical consequences of intra-uterine applications of the direct current are as follows:

1. When an intra-uterine application of 100 or 150 milliamperes produces no reaction, either during or after the application, the uterus is said to be tolerant; the adnexæ are healthy; there is no inflammation to justify surgical interference.

2. When a uterus does not support, or supports badly, 50 milliamperes and reacts after the application, the adnexæ may be considered inflamed.

3. When the intolerance of the uterus is continually growing less and there is symptomatic amelioration, the patient is hysterical, or possesses adnexæ whose inflammation is disappearing.

4. A uterus that does not support 20 or 30 milliamperes and the intolerance goes on increasing, has adnexæ attacked by a lesion that is not amenable to conservative surgery.

The galvanic current gives important indications in the diagnosis and prognosis of uterine fibromata. Galvanic applications are commenced with the positive pole intra-uterine; if the symptoms are ameliorated in a manifest and durable manner the treatment should be continued and recommenced when there is any indication of a return.

If symptomatic relief does not follow these applications and if there is an aggravation, the condition of the adnexæ should be investigated, for the cause of the failure of electric applications will generally be found in them. If the adnexæ are healthy, the uterus should be carefully examined in order to determine the cause of the non-efficiency of electrical applications.

Among the causes of uterine disorders may be cited (1) fibrocystic tumors, (2) malignant degeneration of fibromata.

Gynecological electrical applications, when properly executed are not dangerous and have only two contraindications, pregnancy and inflammation of the peritoneum.

IMPORTANCE OF MEASURING ELECTRIC RESISTANCES IN ELECTRODIAGNOSIS.

70. There does not seem to be much harmony among investigators with regard to the value of the measurements of the electric resistances of the body in the diagnosis of disease. According to some, these measurements are extremely useful, while others deny them any positive value whatever. Vigoroux claims that the resistance of the body is always diminished in exophthalmic goiter, and that in hysteria and melancholia the body resistance is increased. Charcot regarded the diminution of body resistance as an important symptom in the diagnosis of exophthalmic goiter.

D'Arman believes that in epilepsy, idiocy, and infantile paralysis, the body resistance is increased. Rosenthal and Leube, Spehl and Sano formulate contrary opinions. They believe that the differences observed in the value of body resistances are due to the greater or less tendency to perspiration, but are by no means constant.

Spehl and Sano affirm, as the result of 264 experiments on invalids and others, (1) that the most diverse conditions, both in health and disease, may present the same resistance; (2) that whilst certain persons display an absolutely uniform electrical resistance to continuous currents, others, both among the healthy and the sick, show variations even during the course of the same disease; (3) that the same disease presents different resistances in different persons, and variable resistances in the same person.

Doctor Turner considers that much may be learned by an electrical examination of the urine. He states that the specific resistance of normal urine is about 45 ohms, and that its resistance varies, as a rule, inversely with the specific gravity. He considers that the resistance of the urine is a measure for the chemically active substances in the urine—of the salts, and to a much less degree, of the inert urea.

MOTOR POINTS OF THE BODY.

71. It is indispensable, when one desires to investigate the electrical reactions of the nerves and muscles of a patient, to know the exact location of the motor points in order to produce the best possible contraction and to excite only the nerve and muscle that one wishes to study. The **motor points** were first pointed out by Duchenne as those points on the surface of a muscle that responded most energetically to electrical stimulation. In his investigations, Duchenne used the electrodes shown in Fig. 15; these are metallic and, when used, should have their points covered with chamois. By experiments on the cadaver, von Ziemssen subsequently demonstrated that these motor points correspond to the entrance of the nerve-fibers into the muscle. Among the best plates of the motor points may be mentioned those of von Ziemssen, Eich-

FIG. 15.

hortz, Erb, Onimus, and Castex. When the localized application of electricity was recognized as the chief method of treating disease, the motor points were of more importance than they are today. The situation of the motor points is best determined by using a fine electrode, well moistened. The accompanying illustrations from von Ziemssen show the principal motor points of the body. It is recommended as good practice to locate these points by applications to one's own body. In this way, a knowledge of the sensations of the different currents is acquired, as well as the location of the motor points. After locating the motor points, they may be touched with nitrate of silver and photographed.

MOTOR POINTS OF HEAD AND NECK.

1, Frontalis muscle.
2, Attrahens and attollens auriculam muscle.
3, Retrahens and attollens auriculam muscle.
4, Occipitalis muscle.
5, Facial nerve.
6, Posterior auricular branch of facial nerve.
7, Stylohyoid muscle.
8, Digastric muscle.
9, Buccal branch of facial nerve.
10, Splenius capitis muscle.
11, Subcutaneous branches of inferior maxillary nerve.
12, External branch of spinal accessory nerve.
13, Sternomastoid muscle.
14, Trapezius muscle.
15, Sternomastoid musole.
16, Levator anguli scapulæ muscle.
17, Posterior thoracic nerve.
18, Phrenic nerve.
19, Omohyoid muscle.
20, Nerve to serratus magnus muscle.
21, Axillary nerve.
22, Branch of brachial plexus (musculocutaneous and part of median).
23, Anterior thoracic nerve (pectoral muscles).
24, Corrugator supercilii muscles.
25, Compressor nasi and pyramidalis nasi muscle.
26, Orbicularis palpebrarum muscle.
27, Levator labii superioris alæque nasi muscle.
28, Levator labii superioris muscle.
29, Zygomaticus minor muscle.
30, Dilatator naris.
31, Zygomaticus major.
32, Orbicularis oris.
33, Branch to triangularis and levator menti muscles.
34, Levator menti muscle.
35, Quadratus menti muscles.
36, Triangularis menti muscle.
37, Cervical branch of facial nerve.
38, Branch to platysma muscle.
39, Sternohyoid muscle.
40, Omohyoid muscle.
41, Sternothyroid muscle.
42, Sternohyoid muscle.
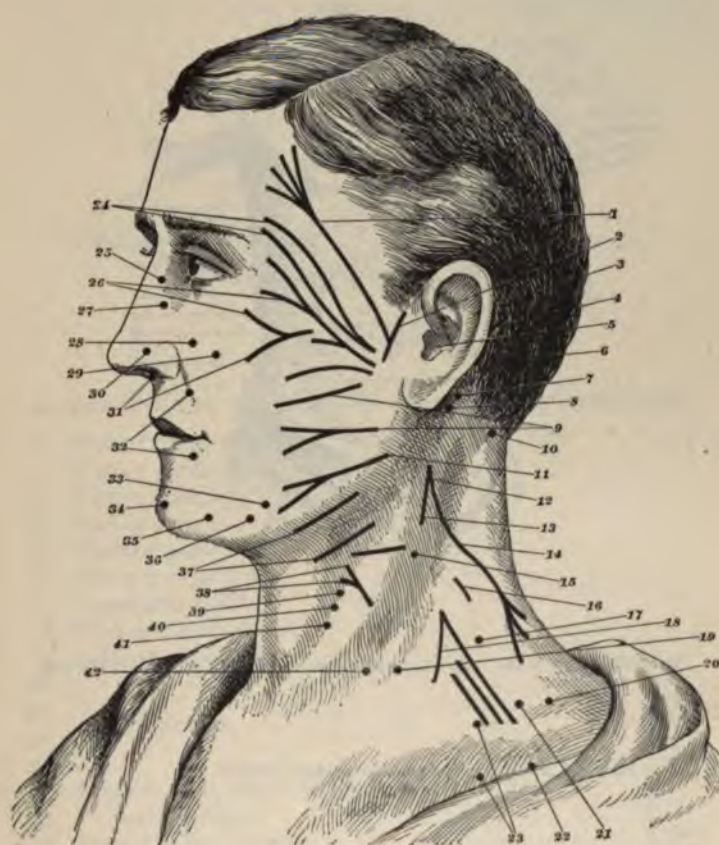
FIG. 16.
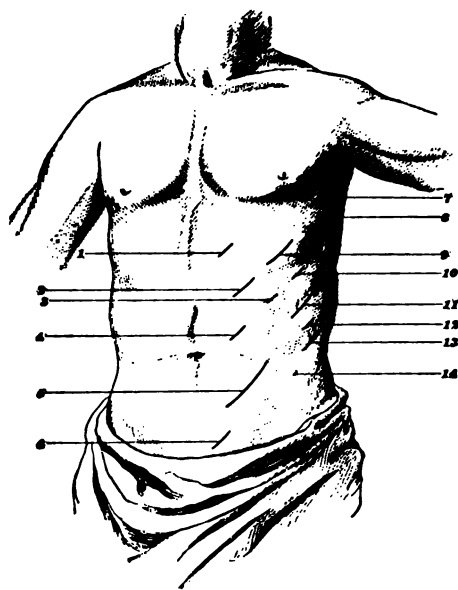
Fig. 17.

MOTOR POINTS OF ANTERIOR SURFACE OF TRUNK.

1,
2,
3, } Rectus abdominis (intercostal nerves).
4,
5,
6,
7, Serratus magnus.
8, Latissimus dorsi.
9,
10,
11, } Obliquus externus (intercostal nerves).
12,
13,
14, Transversalis.
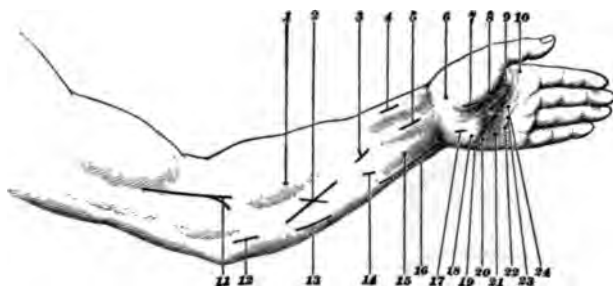
Fig. 18.

MOTOR POINTS OF FLEXOR SURFACE OF FOREARM.

1, Flexor carpi radialis.
2, Flexor profundus digitorum.
3, Flexor sublimis digitorum.
4, Flexor longus pollicis.
5, Median nerve.
6, Abductor pollicis.
7, Opponens pollicis.
8, Flexor brevis pollicis.
9, Adductor pollicis.
10,
22,
23, } Lumbricales.
24,
11, Branch of median nerve to pronator teres.
12, Palmaris longus.
13, Flexor carpi ulnaris.
14, Flexor sublimis digitorum.
15, Flexor sublimis digitorum (index and little finger).
16, Ulnar nerve.
17, Deep branch of ulnar nerve.
18, Palmaris brevis.
19, Abductor minimi digiti.
20, Flexor brevis minimi digiti.
21, Opponens minimi digiti.
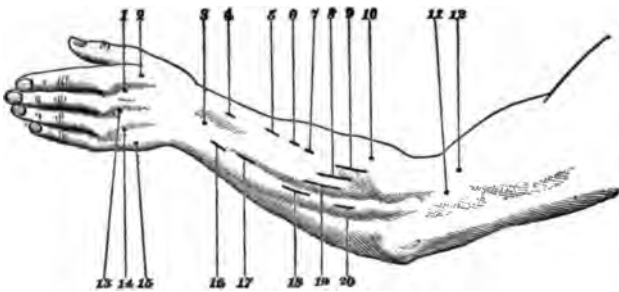
FIG. 19.

MOTOR POINTS OF EXTENSOR SURFACE OF FOREARM.

1,
2,
13, } Dorsal interossei.
14,

3, Extensor indicis.
4, Extensor primi internodii pollicis.
5, Extensor ossis metacarpi pollicis.
6, Extensor indicis et extensor ossis metacarpi pollicis.
7, Extensor indicis.
8,
9, } Extensor communis digitorum.
19,
10, Extensor carpi radialis brevior.
11, Extensor carpi radialis longior.
12, Supinator longus.
15, Abductor minimi digiti.
16, Extensor secundi internodii pollicis.
17, Extensor indicis.
18, Extensor minimi digiti.
20, Extensor carpi ulnaris.
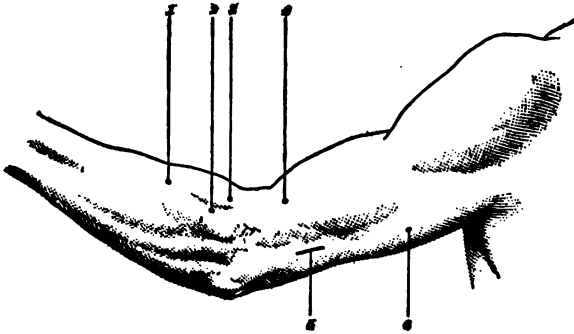
FIG. 20.

MOTOR POINTS OF POSTERIOR OR EXTENSOR SURFACE OF LEFT ARM.

1, Extensor carpi radialis brevior.
2, Extensor carpi radialis longior.
3, Supinator longus.
4, Brachialis anticus.
5, Musculospiral nerve.
6, External head of triceps.
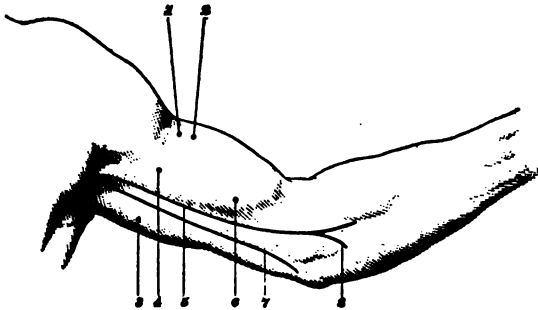
FIG. 21.

MOTOR POINTS OF ANTERIOR SURFACE OF LEFT ARM.

1, Musculocutaneous nerve.
2, Branch to biceps.
3, Branch to long head of triceps.
4, Musculocutaneous nerve.
5, Median nerve.
6, Brachialis anticus.
7, Ulnar nerve.
8, Branch of median nerve to pronator teres.
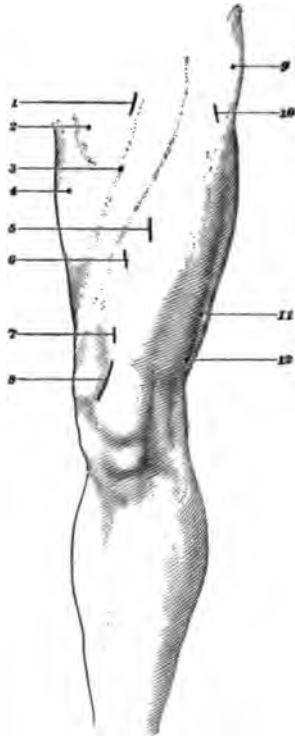
FIG. 22.

MOTOR POINTS OF ANTERIOR SURFACE OF THIGH.

1, Cruralis.
2, Obturatorius.
3, Sartorius.
4, Adductor longus.
5, Rectus femoris.
6, Branch of crural nerve to quadriceps muscle.
7, Cruralis.
8, Branch of crural nerve to vastus internus muscle.
9, Tensor fasciae lat. (Ram. N. glutei sup.)
10, Tensor fasciae lat. (Ram. N. cruralis.)
11,
12, } Vastus externus.
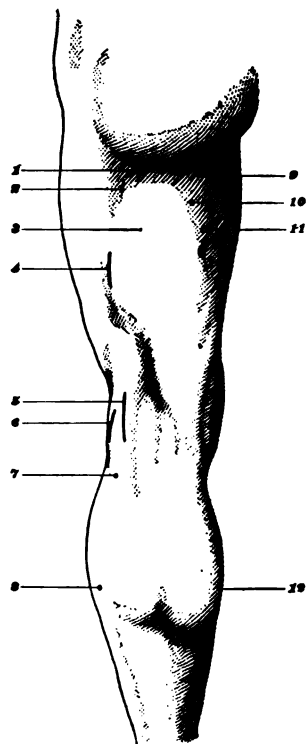
Fig. 23.

MOTOR POINTS OF POSTERIOR SURFACE OF THIGH.

1, Ram. inf. N. glut. inf. pro M. glut. maxim.
2, Sciatic nerve.
3, Long head of biceps.
4, Short head of biceps.
5, Tibial nerve.
6, Peroneal nerve.
7, Gastrocnemius externus.
8, Soleus.
9, Adductor magnus.
10, Semitendinosus.
11, Semimembranosus.
12, Gastrocnemius internus.
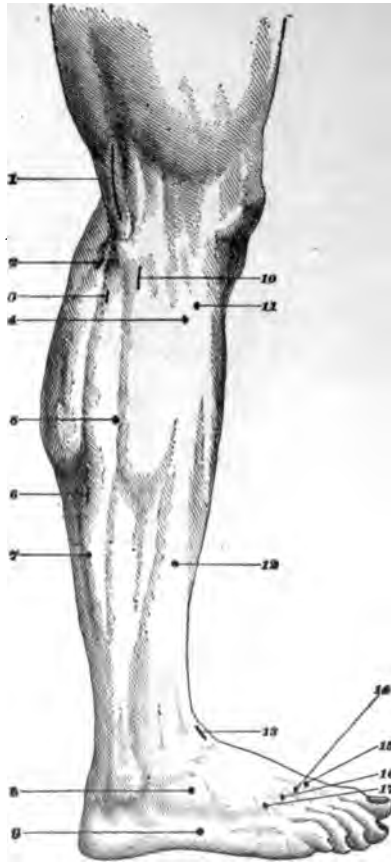
FIG 24.

MOTOR POINTS OF OUTER SURFACE OF LEG.

1, Peroneal nerve.
2, Ext. head of gastrocnemius.
3, Soleus.
4, Extensor longus digitorum communis.
5, Peroneus brevis.
6, Soleus.
7, Flexor longus hallucis.
8, Extensor communis digitorum brevis.
9, Abductor minimi digiti.
10, Peroneus longus.
11, Tibialis anticus.

12, Extensor longus hallucis.

13, { Ant. tibial nerve.
{ Extensor brevis digitorum.

14,
15,
16, } Dorsal interossei.
17,
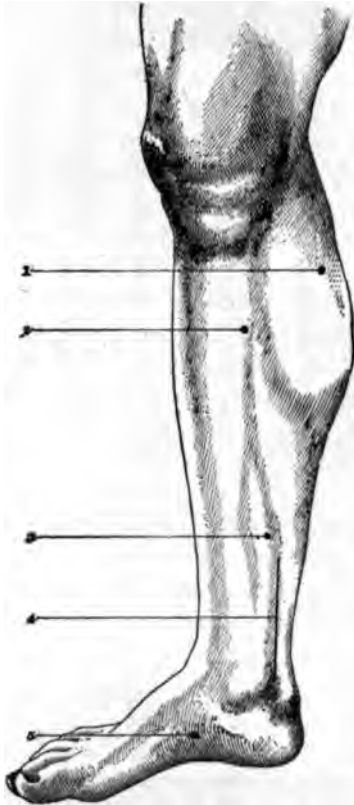
FIG. 25.

MOTOR POINTS OF INNER SURFACE OF LEG.

1, M. gastrocnemius internus.
2, M. soleus.
3, M. flex. digitor. commun. long.
4, N. tibialis.
5, M. abductor pollicis.

72. The following table by Doctor De Watteville is a guide to the seat of a lesion in the diseases of the nervous and muscular systems as far as it can be indicated by the electrical reactions:

NORMAL (A.)

1. Healthy—shamming
2. Functional disturbance of
3. Organic disturbance of
   - Cortex.
   - Corpus striatum.
   - Peduncles.
   - Pons.
   - Lateral columns.

ABNORMAL (B.)

Quantitative alterations

- Increased irritability
  - Peripheral nerves { Very slight disease.
  - Muscles.
  - Irritative processes in { Brain lateral column.
  - Hyperexcitability in { Cornua nerve-muscle.
- Diminished irritability
  - Alterations in nerve-muscle of spinal origin.
  - Alterations in nerve-muscle of idiopathic origin.
  - Alterations in nerve-muscle of post-regenerative origin.

Quantitative and qualitative

- Complete reaction of degeneration
  - Destruction of anterior cornua.
  - Disease of multipolar cells.
  - Disease of trophic centers of nerve-muscle.
  - Severe lesion of nerve-trunk.
- Partial reaction of degeneration
  - Slight disease of multipolar cells.
  - Disease of trophic centers of muscle.
  - Slight disease of nerve-trunk.

73. Points Favorable for the Electrization of Nerves.—In the upper limb:

1. The *median*, along the inner border of the biceps, and at the bend of the elbow.

2. The *ulnar*, in the groove between the internal condyle and the olecranon.

3. The *musculospiral*, at the point where it emerges from the triceps; namely, on the outer side of the upper arm, about the junction of its middle and lower thirds.

4. The *musculocutaneous*, between the biceps and coraco-brachialis.

5. The *long thoracic* (serratus magnus), on the inner wall of the axilla.

6. At a spot 1 inch above the clavicle and a little externally to the posterior border of the sternomastoid, immediately in front of the transverse process of the sixth cervical vertebra, a simultaneous contraction can be produced in the deltoid, biceps, coracobrachialis, brachialis anticus, and supinator longus. This point has been called the supraclavicular point of Erb.

In the lower limb:

7. The *anterior crural*, in the fold of the groin just outside the femoral artery.

8. The *sciatic*, in the pelvic coats of the rectum, or just below the gluteal fold at the back of the thigh.

9. The *peroneal*, or *external popliteal*, just above the head of the fibula, beside the biceps tendon.

10. The *internal popliteal nerve*, in the popliteal space, and to the inner side of the tendon Achilles.

In the face:

11. The *facial*, through the cartilage of the lower surface of the meatus auditorius. Its chief ramifications can be reached where they emerge from the parotid gland. Erb chooses for stimulation three main branches of the facial: (1) for muscles above the palpebral aperture; (2) for those in front of the upper jaw, between the orbit and the mouth; (3) for muscles of the lower jaw. He tests each of these in two places, first at points just in front of the ears, and secondly for (1) at the temple, for (2) at anterior extremity of zygomatic bone near its

lower border, for (3) at the middle of the inferior border of the horizontal ramus of the lower jaw.

12. The *fifth*, at the supraorbital foramen, at the infraorbital foramen, at the mental foramen, on the side of the tongue.

In the neck:

13. The *spinal accessory*, at the top of the supraclavicular triangle, where the nerve pierces the sternomastoid.

14. The *phrenic*, on the outer edge of the lower part of the sternomastoid.

15. The *hypoglossal*, along the upper border of the great cornu of the hyoid bone.

16. The *recurrent laryngeal*, along the outer border of the trachea.

17. The *pneumogastric* and *glossopharyngeal*, along the track of the carotid artery just below the angle of the jaw.

74. Frequently it happens that paralysis affects a group of muscles. It is then necessary in making a diagnosis to trace back the nerve-supply of the affected muscles to their spinal roots. Muscles physiologically related may receive their nerve-supply from different motor roots. The following table, by Doctor Ferrier, gives the more important spinal nerve-roots, with the muscles supplied by each.

Nerve-roots:

4th Cervical.—Deltoid, rhomboids, spinati, biceps; brachialis anticus, supinator longus; extensors of the hand.

5th Cervical.—Deltoid (clavicular portion), biceps, brachialis anticus, serratus magnus, supinator longus; extensors of the hand.

6th Cervical.—Latissimus dorsi, pectoralis major, serratus magnus, pronators, triceps.

7th Cervical.—Teres minor, latissimus dorsi, subscapularis, pectoralis minor, flexors of the hand, triceps.

8th Cervical.—Flexors of wrist and fingers, muscles of hand, extensors of wrist and fingers, triceps.

1st Dorsal.—Muscles of hand: thenar, hypothenar, interossei.

3d Lumbar.—Iliopsoas, sartorius, adductors, extensor cruris.

4th Lumbar.—Extensor femoris et cruris, peroneus longus, adductors.

5th Lumbar.—Flexors and extensors of toes, tibial, sural, and peroneal muscles, extensors and rotators of thigh, hamstrings.

1st Sacral.—Calf, hamstrings, long flexor of great toe, intrinsic muscles of foot.

75. Doctor Heringham gives, from the dissections of the brachial plexus of infants, as the usual nerve-supply, the following table:

3d, 4th, and 5th Cervical.—Levator anguli scapulæ.

5th Cervical.—Rhomboids.

5th, or 5th and 6th Cervical.—Supraspinatus, infraspinatus, teres minor.

5th and 6th Cervical.—Subscapularis, deltoid, biceps, brachialis anticus.

6th Cervical.—Teres major, pronator radii teres, flexor carpi radialis. Supinator longus and brevis. Superficial thenar muscles.

5th, 6th, and 7th Cervical.—Serratus magnus.

6th or 7th Cervical.—Extensors carpi radialis.

7th Cervical—Coracobrachialis, latissimus dorsi, extensors at back of forearm, outer head of triceps.

7th and 8th Cervical.—Inner head of triceps.

7th, 8th, and 1st Dorsal.—Flexor sublimis and profundus, flexor carpi ulnaris, flexor longus pollicis, and pronator quadratus.

8th Cervical.—Long head of triceps, hypothenar muscles, interossei, deep thenar muscles.

The pectoralis major from the 6th, 7th, 8th, and 1st dorsal.

The pectoralis minor from the 7th, 8th, and 1st dorsal.

76. The Dispersing Electrode.—In investigating the electrical reactions of nerve and muscle, the surface area of the active electrode should be small so that it can be adapted to all surfaces. About ¼ inch in diameter is the size usually employed. The inactive or dispersing electrode should be much larger, to diminish current-density, and to prevent the local electrolytic action of the current. The size and position

of the dispersing electrode are right when they annoy neither
the patient nor the physician.   For the usual electrical tests,
the dispersing electrode should have a surface area of about
12 square inches.   It should be made of block-tin or thoroughly
annealed copper, and covered with felt or amidou.   The patient
can easily hold the dispersing electrode in position, leaving the
physician to manipulate the active electrode and the part of
the body under examination.

77.   Electrical diagnosis of nerves and muscles presupposes
on the part of the investigator thorough knowledge of the topo-
graphical anatomy of the human body, and a more than
ordinary familiarity with the technique of electrical appliances.

Fig. 26.

Attention to details
and repeated exercises
in locating motor
points, both on one-
self and on patients,
are necessary to ac-
quire proficiency in
electrical diagnosis.
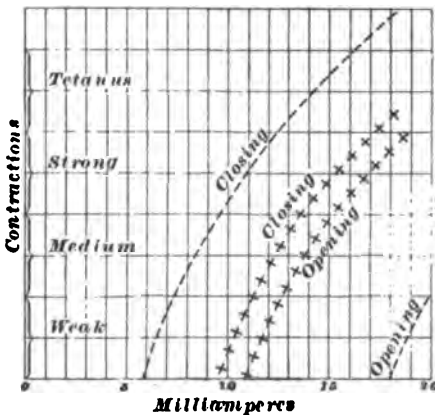
The manner in
which the muscles
contract, the different
muscles that respond
when an electrical
stimulus is applied to
a nerve, the number
of milliamperes required to produce contraction, the resistance
of the skin, and the location of the nerve, whether deep or
superficial, are all matters that should be closely observed.

It is important to have a good method for recording the
results of electrodiagnosis.   Fig. 26 represents the graphic method
proposed by Prof. Bergonié.   Two lines are drawn at right
angles; the horizontal one is the abscissa upon which the
current is noted; the relative amounts of the muscular contrac-
tions are the ordinates.   A curve is thus obtained for negative
and positive opening and closing, showing for each amount of

current the relative extent of the contraction. The curve of the negative pole is marked by the sign —, that of the positive pole by the sign +. The normal law of contraction is expressed in Fig. 26.

78. As *R D* follows disease or injury of the nuclei of origin for the cranial nerves or of the ganglion-cells of the anterior cornua or of the motor nerve-trunks, cerebral or spinal, the importance of disclosing its existence must be apparent. The time required for each examination (which practice considerably shortens) is fully compensated for by a knowledge of the trophic condition of the lower motor segment that is more definite and satisfactory than can be acquired by any other method of examination. *R D* excludes at once the brain, the white matter of the cord, hysterical paralysis, shamming, idiopathic muscular atrophy, and clears the ground in a very appreciable manner for the consideration of other diseases of the cerebrospinal axis.

The tendency to neglect the electrical investigation of nerve and muscle is not easily explained, since the investigation gives definite results that enable the physician to form a prognosis and to institute rational treatment. When muscles and motor nerves are under investigation, the direct current is an indispensable aid.

<div align="center">

MAGNETISM.

</div>

79. Wherever there is an electric current there is a magnetic field—steady, if the current is steady; alternating, if the current is alternating. It is the influence of these magnetic fields on the tissue-metabolism of the human organism that will be considered here. If the properties of a molecule depend on the arrangement of the atoms that compose it as much as they do on the kind of matter, it would be strange if lines of magnetic stress had no influence whatever on the rate of change in life processes. Only a few years ago magnetic fields were believed to have no influence on the human organism. In a paper read before the American Electrotherapeutic Association, in 1892, Doctor Peterson and Mr. Kennelly reported the results of their experiments on this subject. They

gave their conclusions from various experiments, carefully con-
ducted, in the following statement: "The human organism is
in no wise apparently affected by the most powerful magnets
known to modern science; neither direct nor reversed magnet-
ism exerts any perceptible influence upon the iron contained in
the blood, upon the circulation, upon ciliary or protoplasmic
movements, upon sensory or motor nerves, or upon the brain."

It had long been believed by many that magnetism had an
important place among those agencies that control the nutrition
of the human body, both in health and in disease. The
conclusions in the above statement from Doctor Peterson and
Mr. Kennelly were, however, accepted by investigators, because
nothing to the contrary had been experimentally demonstrated.

EXPERIMENTS BY PETERSON AND KENNELLY.

80.   The first series of observations were made on a drop of
water, pulverized iron, powdered hemoglobin, living ciliated
epithelium, and the circulation of the blood in a frog-foot
preparation. These were placed in the field of a microscope,
and inserted between the poles of a powerful electromagnet.
The drop of water and the pulverized iron were influenced
by the magnetic field, but the hemoglobin, the ciliated
epithelium, and the circulation of the blood were in no wise
disturbed.

In the second series of experiments, the influence of stress-
lines on the conductivity of a motor nerve was studied. For
this purpose, a small dog was enclosed for some hours in a
strong magnetic field. The result was negative.

The third and fourth series were the most important, as they
were conducted with a view of determining the physiological
action of steady and alternating magnetic fields on the human
organism. The subject placed his head between the poles of a
powerful electromagnet, which could be excited from a dynamo
machine. They reported as follows: "Five men, ourselves
among the number, were subjected to trial. One case described
will describe all. The subject lay back upon the board and
concentrated his attention upon his sensations. His right

wrist was extended and was grasped by one observer, who took sphygmographic tracings of the pulse. A second observer placed a hand on his chest, to observe any irregularities that might occur in respiration. A third observer, in view of these two, but unseen by the subject of the experiment, opened and closed the switch that excited and released the field, signaling to the first two observers as he did so. The strong magnetic influence was therefore turned on or off at will, and without the knowledge of the subject. Several sphygmographic tracings were taken in each of our subjects, and in one the knee-jerk was tested continuously. The sphygmographic tracings taken during the séance show no change in regularity, in spite of making and breaking of the enormous magnetic influence during its registration. The respirations were not changed in the least. The knee-jerk also presented absolutely no change. As to common sensations, there were none that could be attributed to the magnetic influence, and the subject could not discover when or whether the field had been excited. The testimony of all five subjects was alike.''

The fourth, and final, series was made to test the effect of an alternating magnetic field. The magnetism was reversed 280 times a second. The alternating electromotive force was 1,200 volts, the current supplied being 1.85 amperes.

''Each of the authors acted as subjects in the experiments, permitting the 1,200-volt alternating current to be made and broken frequently in the huge magnetic coil surrounding his head. No effect whatever was experienced. The coil itself hummed with the current, and a strip of sheet iron held in the cavity of the coil, but not touching it, vibrated perceptibly in the hand and gave a distinct, loud sound, which was determined to be middle C of a musical scale.''

81. Doctor Peterson and Mr. Kennelly restricted themselves to a study of the pulse, of the respiration, of the knee-jerk, and of the subjective sensations of the individual in the magnetic field. Physiological chemistry is not mentioned, and received from them no attention whatever. The chemistry of the excretions gives the most reliable data for conclusions on

tissue-metabolism.. The value of chemical analysis of the
excretions is very clearly demonstated in the investigations of
Professor Bouchard on diseases characterized by slowness of
nutritive processes.

If the methods pursued by Bouchard had been adopted by
Doctor Peterson and Mr. Kennelly, they would have been
able to report very different results. The pulse, temperature,
respirations, knee-jerk, and subjective sensations should of
course receive careful study, but it is only by attention to all
the details of these rude experiments," and by a rigorous appli-
cation of the physiological chemistry of digestion, assimilation,
and excretion, that reliable data can be obtained concerning
the influence of magnetic stress on life processes.

Our knowledge of the influence of magnetic stress on animal
functions, in 1892, may be found in the statement from Doctor
Peterson and Mr. Kennelly quoted in Art. 79. Indeed, it was
then universally believed that any action on the human body
attributed to magnetic fields was wholly psychic. It was
about this time that Professor Herdman, of the University of
Michigan, began his series of elaborate experiments to deter-
mine the influence of alternating magnetic fields upon the
metabolic processes of the human organism, and upon the
growth and development of animals.

EXPERIMENTS BY PROF. W. J. HERDMAN.

82. To investigate the influence of alternating magnetic
fields upon man and animals, Professor Herdman caused to be
constructed, in the laboratory of the University of Michigan, a
solenoid 3 feet in diameter, of No. 10 Underwriters' wire, and
with a sufficient number of turns so that a current-strength of
5 amperes produced an average of 65 C. G. S. lines for each
square inch of space in a plane cross-secting the space within
the coil. The current employed to excite the solenoid was
obtained from a Thomson-Houston alternating dynamo. This
dynamo makes 248 alternations a second.

83. First Series of Experiments.—In the first series
of experiments the influence of the alternating magnetic field

was determined by the output of urea. Three subjects were chosen. Two were healthy young men, students of medicine, and the other was a man 38 years of age, suffering from paralysis agitans. He was otherwise in good health. For 1 week before being submitted to the magnetic action, all three subjects were dieted, and the daily output of urea carefully estimated. During the next week, each man was placed comfortably within the solenoid for 2 hours each day. The diet, mode of living, and all other conditions were the same as the first week, with the exception of the alternating field. A careful daily estimate of the urea was made. All the details of control-experiments were rigorously observed. There was no change in respiration, temperature, pulse, or arterial tension. The subject suffering with paralysis agitans claimed a soothing, sedative effect from the magnetic action, and this effect lasted for some hours after he left the solenoid. In all three cases there was an increase of 10 per cent. in the urea eliminated during the second week over that eliminated during the first week. These three experiments show, then, a marked difference in the amount of urea eliminated during two consecutive weeks. As all the conditions were alike during both weeks, except the alternating magnetic field, the increased elimination of urea may be attributed to the magnetic action.

84. Second Series of Experiments.—The second series of experiments was instituted to determine the effects of alternating magnetic fields in retarding or accelerating the growth of young animals. These experiments were made on rabbits and guinea-pigs. Two groups of guinea-pigs and rabbits were chosen as nearly alike in age and weight as possible. The conditions of living and surroundings for each group were similar, except that from 6 o'clock in the evening until midnight one group was placed in a solenoid actuated by a 5-ampere alternating current, and the other group was placed in a similar solenoid not actuated by any current. Each group of animals was treated in this manner until they had reached their full growth.

Professor Herdman has been experimenting in this manner

since 1893, or 1 year after the communication of Doctor Peterson and Mr. Kennelly to the American Electrotherapeutic Association. His control-experiments during these years have been many, and he concludes from his investigations that magnetic energy is in some way transformed into physiological energy, and this increased physiological energy manifests itself in the increased weight, increased growth and development of the animals experimented on, and in the increased elimination of urea in man. From these experiments on animals and man, we cannot escape the conclusion that alternating magnetic fields and quickened tissue-metabolism stand in the relation of cause and effect.

Professor Herdman is still engaged in this line of investigations. In order to satisfy himself and all others who may be interested in the subject as to the genuineness of this relationship of vital activity of animal organism to magnetism. In his recent experiments, the time during which the animals were submitted to magnetic action was lengthened from 7 hours to 12 or 14 hours each day. After a few days, the animals submitted to this magnetic influence showed signs of exhaustion. They became inactive, and sat huddled together in one side of the solenoid. The control animals in the adjoining solenoid were active and lively. At the end of 4 weeks, some of the animals died; and at the end of 5 weeks, all of them had succumbed.

These recent experiments teach that the time during which the animals were placed daily in the active solenoid was too long. Overstimulation was produced, and the animals died of exhaustion. It was, of course, to be expected that if a few hours daily in an active solenoid quickened tissue-metabolism 20 or 30 per cent., 12 or 14 hours, daily, in the same active solenoid must rapidly exhaust the resources of the tissues and produce death. From these experiments, conceived and carried out by Professor Herdman, a rational method of treatment for diseases characterized by suboxidation or retarded metabolism should follow.

ELECTROLYSIS.

INTRODUCTION.

85. There are two methods of investigating the relations of electric currents to living animal tissues—the *physiological* and the *physicochemical.* The physiological method has been employed almost exclusively in investigating the influence of electric currents on the functions of different organs, and in a particular manner on the activity of nerves and muscles under the influence of constant and varying electric-current densities. In this respect it has been established beyond further question that electricity is a nerve irritant capable of extraordinary gradations. Applied to a motor nerve, it produces muscular contraction; applied to a sensory nerve, it produces sensation; applied to a secretory nerve, it produces secretions. We can, by means of electric irritation, better than by any other form of irritant, increase or decrease nerve irritability and accelerate or inhibit nerve conduction in any part of the nervous system.

This method of investigation has been brought to a high degree of perfection by physiologists, and we owe to it the doctrine of electrotonus, our knowledge of electrodiagnosis, and the prominent position occupied by electrotherapy in the treatment of diseases of nerves and muscles. While this great work in physiological research of neuromuscular irritability by means of electric currents was going on, physics and chemistry had accomplished very little with reference to those phenomena by which electric currents are conducted through animal tissues.

Within the last decade physical chemistry has made great progress. The modern doctrine of the ionization of salts in solution enables us to follow the molecular changes that take place in living tissues under the influence of the direct current. This has created a new or second method of electromedical investigation, which in contradistinction to the physiological method is called the physicochemical method. The physico-chemical method has for its basis the electrochemistry of

living animal tissues, and for its correct appreciation it p[..] supposes an accurate knowledge of general electrochemistr[..] Electrochemistry teaches us the relation of electromotive forc[..] to the different chemical bodies. A fluid, such as water, is i[..] a condition to conduct an electric current only when it is an electrolyte, that is, when it contains certain salts or acids in [..]olution. These salts or acids are originally neuter, electrically considered, but when dissolved in a sufficient quantity of water they are decomposed into two component parts, called ions was [..]ers, in such a manner that one part has a positive [..]tric charge, and is called cation, and the other has a negative electric charge, and is called anion. This process is [..] electrolytic dissociation.

86. Action of Electrolytes.—An electrolyte is always a [..] [..] [..] it is a composition of hydrogen with an acid radical, HCl, of a metal with an acid radical, NaCl, or of a metal with hydroxyl, NaOH, or finally of hydrogen with hydroxyl. An electrolyte, in order that it may conduct an electric current, must be either in a fused state or in solution. [..] silver chlorid conducts electricity freely and is itself decomposed during the process. The molecules of aqueous solutions of electrolytes are dissociated into their two ions, which are loaded with their respective electric charges. The component parts of electrolytes move irregularly to and fro. If, however, two electrodes are placed in the solution and a current passed, then, according to Arrheneus, the ions follow definite paths— the anions go toward the anode, and the cations toward the cathode. The ions also move more rapidly under the influence of the current. The electrodes inserted in the solution act like a magnet: they attract opposite charges and repel similar charges. The transport of the ions to their respective poles would be instantaneous were their movement not interfered with by the molecules of water. The first work that the electrolyzing current must do is to overcome the frictional resistances experienced by the ions from the water molecules that stand in their way. These resistances vary in accordance with the nature of the ions—the greater they are the smaller is the

mobility of the ions, and therefore the smaller is their migration velocities. The current has further work to perform at the electrodes; it must neutralize the ions that are attracted to the electrodes, either by drawing away the charges that cling to them or by forming new ions from the material of the electrodes.

We can represent the compositions of an aqueous solution of sodium chlorid schematically; thus,

$$+ \qquad -$$
$$(b)\ Na \qquad Cl\ (c)$$
$$NaCl$$
$$(a)$$
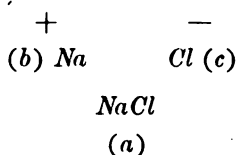
In this schema,

(a) = non-dissociated molecules of sodium chlorid;

(b) = positive sodium ion;

(c) = negative chlorin ion.

All other salts, also acids and bases, whose watery solution conduct electric currents, behave in the same way. Nitrate of silver is decomposed into the positive silver ion, Ag-ion, and the nitric-acid ion, NO_3-ion; chlorate of potassium is decomposed into the positive potassium ion, K-ion, and chloric acid ion, ClO_3-ion. Acids are characterized by the fact that they are decomposed in a watery solution into positive hydrogen ions, and at the same time characteristic negative ions are formed for each acid. The ions of hydrochloric acid are the positive hydrogen ions, H-ions, and the negative chlorin ions, Cl-ions; those of nitric acid are the positive hydrogen ions, H-ions, and the negative nitric-acid ions, NO_3-ions; those of acetic acid are the positive hydrogen ions, H-ions, and the negative acetic-acid ions, CH_3CO_2.

87. Bases and Acids.—Bases are combinations that in a watery solution decompose into negative hydroxyl ions, OH-ions, and at the same time form characteristic positive ions for each base. Caustic potash is decomposed into negative hydroxyl ions, OH-ions, and positive potassium ions, K-ions; caustic soda into negative hydroxyl ions, OH-ions, and positive sodium ions, Na-ions. A watery solution of ammonia is decomposed into

negative hydroxyl ions, OH-ions, and positive ammonia ions, NH_4-ions. This separation of a compound chemical substance in solution into ions having equal and opposite electric charges belongs to the act of dissolving and has nothing to do with an E. M. F. applied from without.

Sodium chlorid dissolved in water ionizes, that is, separates into its two ions, sodium and chlorin, and the solution thus formed is an electrolytic conductor.

88. When sugar or urea is dissolved in water, it does not ionize, that is, separate into its components, and the solution thus formed does not conduct electric currents. Absolutely pure water or pure sulfuric or hydrochloric acid, does not conduct electricity. If the acids, however, are diluted with water they make excellent conductors, that is, their molecules ionize. Water is never primarily decomposed when a current is passed through aqueous solutions of electrolytes. The conductivity of naturally occurring water is to be attributed to the presence of alkali salts in it. It must be clearly understood that the primary action of an electric current when passed through a liquid conductor is to separate the two parts of the electrolyte; hydrogen and the metal (cations) move toward the cathode, while the rest of the electrolyte (anions) move toward the anode.

It occurred to Faraday to send the same current through a series of electrolytic cells arranged one behind the other and containing different electrolytes. It thus became possible to make quantitative comparisons of the changes brought about by the same quantity of electricity in motion. In this way Faraday determined that the amount of chemical action is equal in all parts of a circuit and that the amount of any ions liberated in any given time is proportional to the strength of the current and to the chemical equivalent of the ion. This, with the theory of solution of van't Hoff and the electrolytic dissociation of Arrhenius, is the basis of all work in electrochemistry. The law may be expressed as follows: All movement of electricity in electrolytes takes place only by the concurrent movement of the ions in such a way that equal amounts of

electricity cause chemically equivalent amounts of the different ions to separate.

From this point of view, then, the electric current loses its abstract character. We can see the whole extent of electric conduction and its actions. We know beforehand what must happen under certain conditions if we are sufficiently acquainted with the composition of the conducting substances.

The quantitative phenomena of electrolysis can be calculated from the fact that 1 gram equivalent of the ions carries with it 96,537 coulombs of electricity, as has been determined by experiment. One coulomb causes, then, .000001036 gram of hydrogen ions to separate; hence, it will cause .000001036 $\times a$ grams of any other element to separate, where a is the equivalent weight of the element. In the case of sulfuric acid, H_2SO_4, there are two positively charged hydrogen ions to each negatively charged SO_4 ion. It is assumed in that case that the ion of sulfion, SO_4, carries two negative charges, which it loses when it comes in contact with the oppositely charged electrodes. In the case of ferric chlorid, $FeCl_3$ the cation Fe carries three charges of positive electricity, since each of these anions Cl carries one negative charge.

The strength of acids and bases depends on the degree of their electrolytic dissociation. An acid or a base is stronger, the greater is the concentration of the positive hydrogen ions in relation to the negative hydroxyl ions in its watery solution when similar molecular quantities of this combination have been dissolved.

89. Cations in Physiological Fluids.—Ions belong to a determined class of chemical substances. The inorganic elements that in the body appear only as cations are known in chemistry as alkalin metals. They are principally: Hydrogen, H; sodium, Na; potassium, K; calcium, Ca; magnesium, Mg, and ammonium, NH_4. These ions are always charged with positive electricity, and their principal function is to remove from the body the inorganic anions formed through oxidation processes. They are accordingly found in large quantities in all cells, fluids, and secretions of the body and always appear

with equivalent quantities of anions, **which come partly from** without and partly from the oxidation processes **within the** body. They are therefore of the greatest importance in the metabolism of living tissues, and their diminution is always followed by more or less disturbance.

These anions have no particular action on the body so long as they exist in attenuated solutions. In a concentrated condition they act as corrosives, principally by the extraction of water from the tissues, and thereby cause changes and disturbances in organic substances.

The relative solubility of these cations with anions of different salts is of the greatest importance. The ammonium salts are in a high degree soluble; with calcium and magnesium salts this is not always the case. With certain salts of calcium, the phosphate for example, the more calcium the salt contains the less soluble it is. This combination is frequently formed in the cells as a precipitate when concentration goes beyond the limits of solubility.

90. Anions in Physiological Fluids.—The inorganic elements that appear in the body as anions belong to the group designated in chemistry as metalloids; they are: Ogygen, *O*; carbon, *C*; chlorin, *C*; bromin, *Br*; iodin, *I*; sulfur, *S*; phosphorus, *P*, the most important of these appearing in the body as an anion is oxygen.

These elements can combine directly either with hydrogen or metals to form hydrates or metallic salts, or they can combine with oxygen, forming anions of acid radicals; the most important of the first are hydrochloric acid, HCl, then the chlorids of the alkalin metals, KCl, $NaCl$, $CaCl_2$, $MgCl_2$; of the second, those of importance are sulfuric acid, H_2SO_4; phosphoric acid, H_3PO_4; nitric acid, H_2NO_3; and carbonic acid, H_2CO_3. Chlorin, bromin, and iodin can appear in combination with oxygen, but their action is then altogether different. Potassium chlorid acts quite differently from potassium chlorat within the tissues. The chlorid is almost without action within the tissues, whereas the chlorat has a very deleterious action on the red blood corpuscles. Oxygen combinations with bromin and iodin behave

in the same manner.   Solutions of hydrogen or metals in combination with sulfur or phosphorus have a very energetic action on the tissues of the body, while those of oxygen combinations are much less, as they are being constantly eliminated from the body.   In this respect the solidity of the chemical compounds plays an important part.   The combinations of chlorin, iodin, and bromin with metals, as $Na\,Cl$, KBr, KI, are very solid combinations, while the oxacid combinations of chlorin, bromin, and iodin are not; the oxacid combinations of sulfur and phosphorus are very solid.   Carbon appears in the body as an anion in combination with oxygen; the combinations of carbon with hydrogen, oxygen, and nitrogen in organic chemistry are for the most part very poor conductors of electricity. All the fluids of the body contain a surplus of alkalin bases; acids, however, do not appear as such, but in combination with alkalis, and are only found in the secretions of the body as excretory products.   The conductivity of electrolytic fluids of the body depends on their contents in acids, salts, alkalis, and water.   All electrolytic fluids of the body contain ions that are charged with enormous amounts of electricity.   When electrodes are applied to the body they become charged by the current that passes to them, and attract or repel electrostatically the charged ions in solution, since like charges repel and unlike charges attract one another.   The ions are separated in this way and gather around the electrodes.   As soon as the difference of potential of the two electrodes becomes great enough, the ions give up their charges and assume the ordinary state of elements.

91.   In the case of the conduction of a current by a metal, it is necessary for equal currents of positive and negative electricity to go in opposite directions.   In electrolytes this was found by Hittorf to be unnecessary.   It is always necessary however for the solution to contain equal amounts of positive and negative ions, and as long as this condition is fulfilled, the conduction may take place by the movement of equal or unequal amounts of the positive and negative ions.   If the unit quantity of electricity is passed through the solution, one-half may be transported by negative ions and one-half by positive

ones, or three-fourths by negative and one-fourth by positive, etc. In other words, it has been found that ions are moved with varying velocities by the electric current, and their velocity depends on the kind and number of atoms that the ion contains. This regulated movement of ions toward the poles of the solution constitutes the electric current in which each chemical equivalent of an anion carries a like quantity of negative electricity to the positive pole, and each chemical equivalent of cation carries a like quantity of positive electricity to the negative pole. The transport of ions in electrolytic conductors from pole to pole is therefore inseparably associated with the transport of electricity.

It is very important to know what becomes of the ions when they reach the poles of the electrolytic solution. Here two conditions must be considered. If the metallic terminals of the electric current are placed directly into the electrolytic solution (in this case solution of $NaCl$), the ions will give their electric charges to the metallic terminals or electrodes, and thereby lose their ion qualities. The sodium ion becomes sodium metal, and the chlorin ion becomes chlorin gas in *statu nascendi*. Deprived of their electric charges, the ions behave differently according to their usual chemical affinities. They either enter into combination with surrounding substances or they separate themselves unchanged from the solution in the form of gas or metal. If, however, the metallic terminals or electrodes are separated from the electrolytic solution by another fluid conductor, the ions retain their electric charges and pass unchanged into this fluid conductor. In consequence of this there is an interchange of ions between these two fluid conductors. The positive pole, or terminal, repels cations from its solution into the other electrolytic conductor and attracts anions from that conductor. The negative pole, or terminal, repels anions from its fluid conductor into the other fluid conductor and attracts cations from that conductor. The electric current produces at the surface of contact of the fluid conductors, substitution products out of the component parts of both electrolytes. If we take, for example, a solution of sodium chlorid and apply at both poles a solution of iodid of potassium, on passing an

electric current on one pole of each solution chlorid of potassium will be formed, and on the other pole of each solution iodid of sodium, as substitution products of new formation.

These two conditions—the metallic terminals placed into the electrolytic solution and metallic terminals separated from the fluid conductor by an intervening fluid conductor—are extremely important and should be clearly understood by the student, because they are accurately realized in the routine applications of the direct current in therapeutics. The first of these conditions is realized when metallic needles are inserted into the tissues of the body, and the second when the metallic base of an electrode is separated from contact with the body by means of a compress of gauze, cotton, or amadou saturated with some electrolytic solution.

The electrolytic current applied from without has nothing to do with the separation of a compound chemical substance in solution into its two ions, which are loaded with opposite and equal electric charges; this is affected by the act of dissolving. When there is a sufficient difference of potential created at the poles the electric current separates the ions in obedience to the electrostatic law—like charges repel, unlike charges attract. The negatively charged ions are attracted by the positive pole and the positively charged ions by the negative pole. When the ions reach their respective poles they give up their electric charges and assume the ordinary state of elements. In this state they enter combinations with surrounding substances and to the changes that they produce at the electrodes the name of **electrolysis** is given.

_____

ELECTROCHEMICAL CHANGES IN THE SKIN.

92. If we place platinum electrodes having an area of 1 square centimeter on the dry skin and allow a direct current of 2.5 milliampere to pass for 1 minute, there will be produced in the skin beneath the electrodes punctiform transparent corrosive action. This action on the skin is electrolytic and is entirely due to the action of the direct current. When we speak of the human body as an electrolytic conductor, we refer to solutions of its inorganic salts, chiefly sodium chlorid. The

... chemical explanation of the caustic action on the skin is ... matic acid is formed at the anode and caustic soda at ...

... late the quantity of electricity used in this experi-

$$\frac{2.5 \times 60}{1,000} = .15 \text{ coulomb.}$$

... of electricity forms on the anode .00005478 ... acid and on the cathode .00006 gram caustic ... then into the skin of these quantities of ... matic acid produces manifest disturbances ... disturbance in the skin is due to the ... irritative ions may be proved in the ... beneath the electrodes compresses of ... compress beneath the anode with ... solution and that beneath the ... lution of caustic soda and allow ... pass for the same time, the results ... same. If no current is passed ... contact of the saturated com- ... are therefore due to the cur- ... stronger or weaker or the ... require a correspondingly ... the same result. This experi- ... the application of Fara- ... of small quantities of

... electrodes and the skin com- ... the compresses with a 5-per- ... a direct current of $2\frac{1}{2}$ milli- ... through the circuit thus formed, ... anode will be covered by shining eleva- ... nodes which on the following day form a ... anode there is no caustic action even when ... length of the current are increased.

... of the difference in polar action is to ... general chemistry, but in electrochemistry. ... electrochemistry, according to Faraday's law,

that when a direct current passes through an electrolytic solu-
tion all the anions are moving toward the anode and all the
cations toward the cathode. The conducting fluids of the body
may be represented as a solution of sodium chlorid. We
have then:

BEFORE THE EXPERIMENT.

Anode.	Physiological Fluid.	Cathode.
Na Na Na Na	Na Na Na Na	Na Na Na Na
OH OH OH OH	Cl Cl Cl Cl	OH OH OH OH

AFTER THE EXPERIMENT.

Anode.	Physiological Fluid.	Cathode.
Na Na Na	Na Na Na Na	Na Na Na Na Na
OH OH OH OH Cl	Cl Cl Cl OH	OH OH OH

The current has produced the following changes: At the
anode $2OH$ have been separated from the body and at the
cathode $2Na$ have been separated from the body. From
the contact surface between electrode and skin on the anode
side $1Na$ has entered the body and $1OH$ has left it. This
process has formed $1NaCl$ in the solution on the electrode,
while in the body no change has taken place.

From the surface of the contact between the electrode and
skin on the cathode side $1Na$ has left the body and $1OH$ has
entered it. This process has not changed the soda solution on
the skin but it has formed caustic soda in the body itself, and
to the formation of $1NaOH$ within the body must be attributed
the caustic action of the skin. The electrochemical explana-
tion of the polar action enables us to form important conclusions
of a practical nature. If the laws of electrochemistry are
applicable to living tissues (and this seems very probable), we
can by a proper arrangement of solutions of acids, alkalies, and
salts, and in fact of all electrolytic solutions, introduce them
through the uninjured skin into the body. The quantity of
the electrolyte introduced into the body will depend entirely on
the duration and strength of current.

94. If the compresses are saturated with a 4.5 per cent.
hydrochloric-acid solution and a current of 2.5 milliamperes is

employed for 1 minute there will be beneath the anode trans-
parent pin-head elevations that on the next day form a crust.
On the cathode side there is no change. The following
schema will explain the changes that take place:

BEFORE THE EXPERIMENT.

Anode.	Physiological Fluid.	Cathode.
H H H H	Na Na Na Na	H H H H
Cl Cl Cl Cl	Cl Cl Cl Cl	Cl Cl Cl Cl

AFTER THE EXPERIMENT.

Anode.	Physiological Fluid.	Cathode.
H H H	H Na Na Na	Na H H H H
Cl Cl Cl Cl Cl	Cl Cl Cl Cl	Cl Cl Cl

From these experiments it is clear that by employing different
ions on the electrodes we can produce different chemical actions
in the skin. The hydrogen ions of hydrochloric acid enter the
skin from the anode and produce violent irritation; the hydroxyl
ions, OH, of caustic soda enter the skin from the cathode and
produce violent irritation also. On the other hand, the sodium
ions that enter the body from the anode, and the chlorin ions
that enter the body from the cathode, produce no irritation in
the skin.

These ions represent two extremes, one set producing no
irritation and the other, violent irritation. Between these
extremes there is a wide range of irritant action, according to
the ions employed. The most irritant ions introduced from the
cathode are the hydroxyl group, while next come the acid
radical group; this latter group forms sodium salts in the tissues
and is comparatively well borne. In this way iodin may be
introduced from the cathode from a solution of potassium iodid
so that it can be detected in the urine and without producing
any irritation of the skin other than transitory redness. Other
acid radicals produce inflammatory irritation with pigment
formation. For the anode, we have for consideration chiefly
the metal ions. Their action in the tissues corresponds to the
actions of the different metal chlorids. For some of these living
tissues have great tolerance, as, for example, sodium chlorid;
others produce inflammatory reaction, as Ca; while still others

cause necrosis with either liquefaction of the tissues, as Zn, or with mummification and characteristic pigmentation, as Fe, Ni.

95. Application of Faraday's Laws to Therapeutics.—This application of Faraday's laws to the therapeutic uses of the direct current is of the utmost practical importance in two respects:

1.   By using ions that do not irritate the skin, as sodium ions for the anode and chlorin ions for the cathode, we can employ greater current-strengths for longer periods without causing electrolytic destruction of the skin. In this way Frankenhauser (to whom the original work in this line is due) used 50 milliamperes for 6 hours and higher intensities for shorter periods.

2.   The majority of medicaments may be introduced into the skin over selected areas and in doses regulated by the strength of current and the length of the application. The medicament may be in solution on the ordinary electrode or in water in the form of the hydro-electric bath. The use of Faraday's law in therapeutics is of especial value in dermatology.

INTERPOLAR ELECTROCHEMICAL CHANGES.

96. The phenomena of the transport of ions under the influence of the direct current suffice to explain not only the polar but also the interpolar and electrotonic effects. The human organism is not a homogeneous body. Chemical changes take place between molecules all along the circuit. These changes in the interpolar area were pointed out by M. Weiss in 1890 and later by Hermann and other physiologists. The current is conducted through the body either through different parts of the same tissue or through different tissues in juxtaposition.

The changes that result from the transport of ions in the same tissue do not modify the composition of the tissue, because for the same tissue the composition of the fluid of each cell is uniform. In consequence of this, each part cedes to the following what it receives from the preceding; in other words, each cell gives to the following cell what it received from the preceding cell. When the changes take place between different

tissues in juxtaposition, the chemical composition of each tissue is modified because the liquids that impregnate the tissues differ from one tissue to another, so that each tissue receives from its neighbor elements foreign to its composition.

The human body is composed of half solid elements that are impregnated with and surrounded by liquids. Between these elements, cells, and the surrounding liquid there is an incessant interchange of water and of organic and inorganic substances in solution. The current in its passage through the body modifies the constitution of liquid that impregnates each tissue. These modifications are evidently in proportion to the intensity of the current employed. If these effects are difficult to appreciate in an objective manner when the direct current is applied to the human body in ordinary therapeutic applications, it is altogether different when high current-intensities are employed. The ions transported under the influence of high current-intensities can produce considerable disturbances in the tissues, and even death, as has been established by d'Arsonval.

As a result of the chemical action, polar and interpolar, there is produced an E. M. F. of polarization that acts in an inverse sense to the original current. One can demonstrate this E. M. F. in every galvanic application. To do this it suffices after the current has passed for a certain time to leave the electrodes in position and connect them with an external circuit that includes a galvanometer; the needle of the galvanometer will be deflected.

_____ __

CATAPHORESIS.

97. The fact has been long known that a movement of electrolytic fluids comparable to osmose takes place in the direction of flow of the current, namely, from the positive to the negative pole. Fluids can in this way be made to pass through membranes or porous diaphragms against the force of gravity. Solid particles are also carried with the current. The globule of mercury, as illustrated in the glass tube, Fig. 27, can be moved back and forth with the current, and when the tube is somewhat inclined the globule is forced with the current against gravity. If a direct current is passed through a piece of muscle removed from the body, the negative end will become

swollen from the accumulation of fluids and solids there, and the positive end will become dry and mummified due to the action of acids and absence of fluids.

A good picture of the cataphoric action of the direct current may be obtained in the following manner: Place platinum electrodes ($\frac{1}{2}$ square centimeter each) on the surface of the forearm. Between the platinum and the skin at the anode, place a compress of filter paper saturated with a solution of sodium bicarbonate; and place another compress saturated with a solution of hydrochloric acid between the platinum and the skin at the cathode. After the passage of the current the difference between the skin at the anode and cathode is very evident. Where the
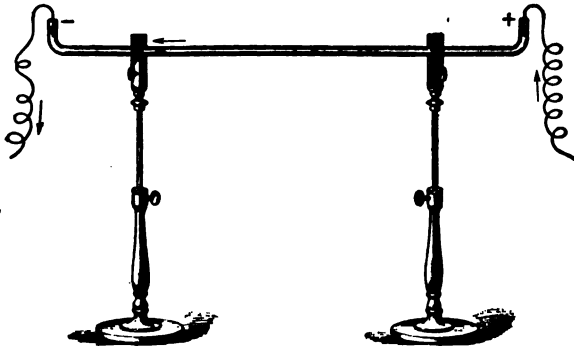
Fig. 27.

anode was placed the skin is sunken in and shriveled; where the cathode was placed, the skin is swollen, white, and edematous. In this experiment, by introducing sodium ions, which are well borne by the tissues, from the anode into the body and chlorin ions, which are also well borne by the tissues, from the cathode into the body, we prevent electrolytic action in the skin and obtain cataphoric effects. Cataphoresis has received considerable attention, and much importance has been given to it in electrotherapeutic textbooks.

We have seen that an electrolyte is partly separated into its two ions, which are loaded with equal and opposite electric charges, and that when a direct current is passed through this solution the positively charged ions, according

to the law of Faraday, move to the negative electrode and the negatively charged ions move to the positive electrode. All the molecules of an electrolyte, however, do not separate into their two ions; a certain number for each substance remain entire. These unchanged molecules are important, for they are responsible for the cataphoric action of the direct current. At the same time that the direct current causes the anions to move toward the anode and the cations toward the cathode, it also causes the unchanged molecules to move in the direction of the current—from the positive to the negative pole. **Cataphoresis** may, therefore, be defined as the transport of the unchanged molecules of an electrolyte in solution in the direction of the current 'from positive to negative pole.

98. For the most part the introduction of medicaments into the body is a property of electrolysis and takes place in accordance with the law of Faraday—anions move toward the anode and cations toward the cathode. The movement of the unchanged molecules or cataphoresis is also important and deserves special mention.

The transport of the unchanged molecules from pole to pole takes place only under the influence of a certain amount of electric energy. In order to be of service therapeutically, the current must move the unchanged molecules not only in one electrolyte, but also from one electrolyte into another. The resistance of the direct-current circuit increases with the duration of the current. This is a very important consideration and must be provided for in cataphoresis. It is a demonstrated fact that the direct current forces molecules of one electrolyte into another electrolyte when the first is a better conductor than the second. In practice, therefore, the fluid with which the electrode is saturated must conduct better than the body. Another fact that must be considered in the practical application of cataphoresis is that under the influence of the direct current the molecules of a poor conducting solution move more rapidly than those of a better conducting solution. From this it follows that there will be a zone in the body (poor conductor) beneath the anode from which molecules have

departed before their place can be taken by molecules from the fluid of the electrode (better conductor). There results then beneath the anode a drying process, which means increased resistance. This resistance will be able to reach a maximum when the conductivity is 0; cataphoric action will then cease.

99. In using cataphoresis therapeutically, current direction should be changed every 5 minutes in order to reduce resistance, and both electrodes should be saturated with the medicament that it is desired to employ and should be placed close together on the surface that it is intended to influence with the medicament.

As the quantity of medicament that can be introduced is at best small, the solution should be concentrated. The voltage of the current should be relatively high, 15 to 20 volts, and the current-strength relatively low; 5 milliamperes should not be exceeded.

Regarding the distribution of medicaments introduced into the body in this manner, it must be understood that the current carries them no farther than the vascular layer of the skin. When medicaments reach the vascular layer of the skin they are taken up by the lymph channels and transported to all parts of the body. We may, therefore, expect as a result of cataphoric medication either a local or a general action. To reach tumors situated in the deeper structures of the body, as in the liver, by the local action of cataphoresis is entirely out of the question. Both the local and general action of various drugs introduced into the body by cataphoresis are at times urgently demanded; its technique should therefore be familiar to every physician. The drugs most frequently employed in cataphoresis are the corrosive chlorid of mercury, 2-per-cent. solution potassium iodid, quinin, cocain, and arsenic.

GALVANOCOCAIN ANESTHESIA.

100. Method of Application.—Neither the electric current nor cocain separately applied to the skin produces complete anesthesia, but a solution of cocain used upon the positive pole will produce a decided anesthetic local effect. A 15- or 20-percent. solution of cocain in water may be used in the following

manner: Fill the reservoir of the block-tin electrode, shown in Fig. 28, with the cocain solution. Cover the perforations in the electrode with a piece of blotting-paper, also saturated with the solution, and apply the electrode to the skin. Make the electrode positive, and turn on, through the rheostat, a current of 5 milliamperes for 10 minutes. With an 8-per-cent. aqueous solution, at least 10 minutes will be required to produce local anesthesia. The negative pole is held in the hand of the patient. Aqueous solutions of cocain have been used with very good results for the relief and cure of very obstinate forms of neuralgia. Cocain used in this way will find many applications in routine practice. It does not, however, when dissolved in water, produce sufficient anesthesia for the performance of minor surgical operations. Before applying the electrode armed with aqueous solutions, the skin should be first freed from its fats by thorough washing with soap and water.

Fig. 28.
Dr. W. J. Morton's Electrode.

101. Guaiacol Solutions.—Galvanococain anesthesia produced with an 8-per-cent. solution of cocain in guaiacol is profound, and has very much facilitated all the operations of minor surgery. Galvanococain anesthesia with the 8-per-cent. guaiacol solution is produced in the following manner: In using the guaiacol-cocain solution, no preparation of the skin is necessary. The reservoir of the block-tin electrode is first filled with the solution, and the perforations covered with a circular piece of blotting-paper saturated with the solution. The electrode is made positive, and applied gently but firmly to the part to be anesthetized. The negative electrode is held in the patient's hand. Turn on through the rheostat a current of from 1 to 3 milliamperes. This will in 2 or 3 minutes produce profound cocain anesthesia, which will last for 30 minutes. A rheostat and a milliammeter are necessary in the circuit. If the current is gradually turned on through the rheostat, and

after 3 minutes' duration gradually turned off in the same manner, the patient experiences absolutely no pain. Eight per cent. is the strength of the solution generally employed, but it may be used with perfect safety as strong as 30 per cent. Up to the present time there have been reported no cases of constitutional effects ascribed to the use of cocain in this manner. Electrodes of different sizes and shapes are manufactured, adapted to the extent and location of tissues to be anesthetized. The guaiacol seems in some way to localize the action of cocain, and to prevent its diffusion into the general system.

102. It is claimed by some authors that the introduction of cocain into the tissues by means of the direct current is an electrolytic and not a cataphoric action. Doctor Price is of the opinion that the underlying force in cataphoresis is simple electrolysis. He believes that cocain is split into ions first and that the electronegative ion is the part that enters the tissues and produces the anesthetic effect. If it can be shown that the electronegative ion of the cocain solution is an anesthetic, then the theory of Doctor Price becomes most plausible, and instead of this process being a cataphoric action, it is electrolytic pure and simple. There can be no doubt that electrolysis is going on to a large extent; this is perhaps the greatest part of the action in the cavity of a tooth, as is shown by the active liberation of gas and the rapid change to a strong acid reaction. We believe, however, that following the law of electrical osmose a portion of the cocain is carried into the tissues without having suffered decomposition.

The laws governing electrolysis are fixed and in like manner are those governing osmose. Both processes are going on at the same time, but as the anesthetic property of the electronegative ion is not yet demonstrated, we feel justified in attributing the anesthesia to the cataphoric action of the direct current.

METALLIC INTERSTITIAL ELECTROLYSIS.

POLAR ACTIONS WITH BARE ELECTRODES.

103. When clean metallic plates are placed in contact with cutaneous or mucous surfaces or when metallic needles are plunged into the tissues, electrolysis of the tissues takes place, the amount of which will depend on the intensity of the current and the duration of its flow.   The chemical processes that take place under these conditions cause accumulation of acid ions at the positive pole and alkalin ions at the negative pole.   The portions of tissues immediately beneath or around the electrodes are thus destroyed and become separated from the unaffected tissue by a line of demarcation.   The extent and consistency of the eschar will be greater or less, depending on the polar action that produces it.   Electrolytic action that is brought about at the positive pole is known as *anodic electrolysis*, while *cathodic electrolysis* refers to the action produced by the negative pole.

In the body, constituted so largely of water and various salines in solution, the anions that appear at the positive pole are oxygen, chlorin, and the acids; the cations at the negative pole are hydrogen and the bases.   If these are disengaged in sufficient quantity the caustic effects are characteristic at each pole and have been specially applied in therapeutics by Tripier and Apostoli under the name of galvano-chemic cauterization.

104. The different methods of making use of the chemical action of the direct current depends on the following experiments:

Insert two platinum electrodes into fresh egg albumen and allow a direct current of 50 milliamperes to pass.   Bubbles of gas will be evolved at both poles.   At the anode, coagulation will take place, while at the cathode the albumen will be liquefied.   Coagulation characterizes the action of the positive pole and liquefaction that of the negative pole.

Insert two steel needles into a piece of beef muscle; connect

one with the positive pole and the other with the negative pole of a direct-current source, and submit the beef muscle to a current of 100 milliamperes for 2 minutes. Bubbles of hydrogen will escape from the track of the negative needle accompanied by a hissing sound. The positive needle is firmly fixed in the tissues and is withdrawn with difficulty. If an incision is made into the beef muscle alongside the negative needle it will be found to be surrounded by a cavity containing liquids and bubbles of hydrogen gas. This needle is as bright as before the experiment. If the positive needle is allowed to remain in place and cut down upon, it will be found to be corroded and firmly fixed in a greenish eschar; if it is made of platinum, or other metal not attacked by the nascent oxygen and chlorin, the tissues around it will show an uncomplicated picture of anodal electrolysis—the characteristic hardening and searing of an acid application. The non-corrodible platinum needle is not so firmly fixed in the tissues as is the steel needle. These drying and coagulating effects around the anode, and the softening liquefying effects around the cathode, are among the best known facts in experimental science. The negative needle remains clean and bright regardless of what metal it may be composed. On testing with litmus solution the reaction of the froth at the negative pole is alkalin and that at the positive pole is acid in reaction.

The extent of destruction at each pole with a given current-strength is of much interest in the treatment of tumors. Doctor Massey has made the estimate that 200 milliamperes concentrated at the ½-inch exposed end of a negative needle will destroy an area of this length and ¼ inch in diameter in the muscular tissue of the cadaver, if passed through for 2 minutes. In a living carcinomatous tumor of the breast, he has produced a necrotic area about 2 inches broad and 1 inch in depth by 1,000 milliamperes in 10 minutes.

METALLIC INTERSTITIAL ELECTROLYSIS.

105. It has already been pointed out that hydrogen and the metals are introduced into the body from the positive electrode, or anode, and that the acid radicals, including the

halogen and hydroxyl groups, are introduced into the body
from the negative electrode, or cathode. The action of the
metal in the tissues will correspond to that of the oxychlorid
of the metal in question. When the anode is formed of an
oxidizable metal the products liberated on its surface are oxygen
and chlorin, if we suppose the organism composed simply of a
solution of sodium chlorid. Oxygen and chlorin react on the
metal forming oxychlorids. If the current continues to pass
there will be an interchange between the organism and the
oxychlorids, which may be represented by the following schema
in which the metal is represented by the letter M:

$$+ OClM \quad OClM \quad H_2O \quad H_2O$$
$$+ OCl \quad MOCl \quad MO \quad H_2O \quad H_2O$$
$$+ OCl \quad OCl \quad MO \quad MO$$
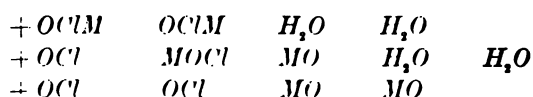
The current causes the liberation of oxygen and chlorin at
the anode and at the same time transports the metal from
molecule to molecule within the tissues. When the electrode
employed is soluble; that is, one attacked by the oxygen and
chlorin formed in the tissues, the resulting polar action differs
from that produced by insoluble electrodes, as gold, carbon,
and platinum. The soluble electrodes most generally employed
are made of copper, zinc, or silver. The products of electrol-
ysis with insoluble electrodes are deposited on the surface of
the tissues that they destroy. The metallic oxychlorid formed
by the chemic action of the nascent oxygen and chlorin is,
according to the theory of ions, transported from molecule to
molecule, penetrating into the depths of the tissues where its
action depends on the metal employed as the electrode, whether
copper, silver, or zinc.

106. The difference between the actions at the poles of a
direct current applied to living animal tissues is due to the dif-
ference in chemical action of anions and cations. When an
insoluble electrode is applied to a cutaneous or mucous surface
or plunged directly into the tissues, the anions and cations
at the respective poles are always the same and depend on the
chemical composition of the tissues. In the case of soluble
electrodes, the cations formed at the positive pole are determined

by the composition of the + electrode and one can produce
in the tissues at will copper, silver, or zinc ions.

In 1893, Dr. George Gautier investigated the effects of copper
ions on the tissues. He inserted copper needles into the
muscles of a rabbit's leg and passed a current of 9 milliamperes

FIG. 29.
Soluble Needles.

for 10 minutes, Fig. 29. Both needles were carefully weighed
before and after the experiment and the difference in weight
was for one needle .00012 gram. and for the other .00025 gram.
This loss represents the quantity of copper deposited in the
tissues. He also injected the oxychlorid of copper into rabbits
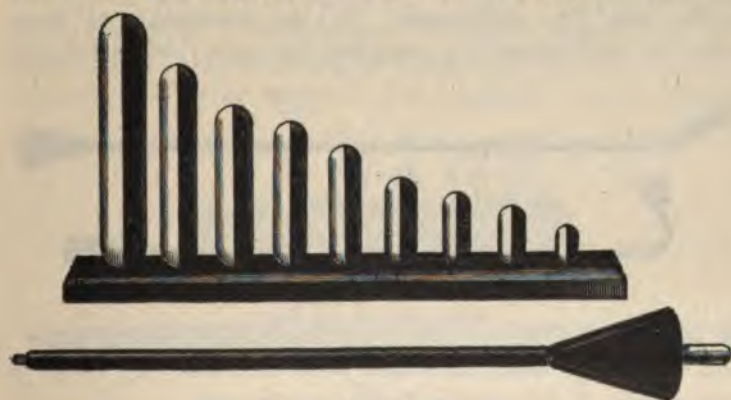
FIG. 30.
Protected Soluble Bulbs.

and from the results obtained concluded that the salt of copper
was not toxic.

The oxychlorid of copper penetrates the tissues in direct
proportion to the intensity of the current and the duration
of its flow.

Doctor Gautier made ten applications with a copper electrode in the interior of the uterus of a rabbit during a period of 2 months: After the fifth application he performed laporatomy to examine the condition of the uterus and found no traumatic lesion, not even congestion.   During the laporatomy he made an application of 20 milliamperes for 10 minutes.   The appearance of the oxychlorid was very manifest not only on the surface of the mucous membrane, but intracellular diffusion was

FIG. 31.

also evident.   The abdomen was closed and the animal left alone for 10 days, after which time four more applications were made.   After these last applications total ablation of the uterus was performed, and it was observed that (1) the deposit of copper salts on the internal surface of the mucous membrane of the uterus was very appreciable; (2) the penetration of these salts into the tissues was complete, the parts, both externally
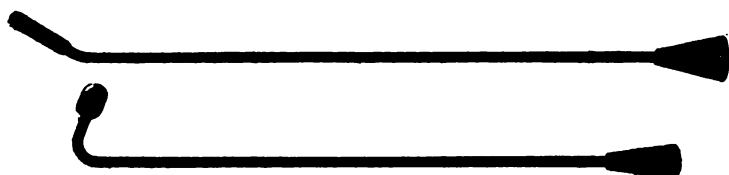
FIG. 32.
Soluble Electrode, Post-Nasal.

and internally, being saturated with insoluble oxychlorid of copper and of the soluble organometallic salt.

107.   The instrumentation of metallic interstitial electrolysis is of the simplest.   The current-strength generally employed is from 10 to 40 milliamperes and the duration of each séance from 10 to 20 minutes.   This makes the apparatus very simple and portable.   The copper employed must be chemically pure, red copper, electrolytic copper.   After having

been carefully washed, and polished with emery-paper, the electrode should be placed in a flame and then cooled in a weak solution of formalin or camphorated ether before each application.
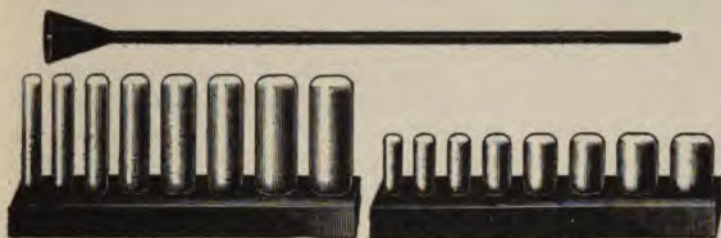
FIG. 33.
Soluble Bulbs.

It is claimed by Weill that cupric interstitial electrolysis in the treatment of hemorrhagic metritis is superior to all medical treatment, and even to curetting. It requires the greatest care in its technique; it must be aseptic both as regards the vulva and vagina. Cupric interstitial electrolysis has also been found superior to all other agents in the treatment of ozena, or fetid
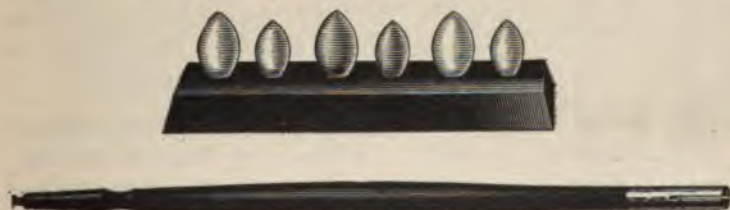
FIG. 34.

catarrh. The essentials of metallic interstitial electrolysis are (1) prolonged sittings, extending even to 20 minutes; (2) feeble currents, 10 to 40 milliamperes; (3) chemically pure electrolytic copper. Figs. 30, 31, 32, 33, and 34 represent electrodes used in metallic electrolyses.

POLAR PROPERTIES OF DIRECT CURRENT.

108. The polar properties, both biological and physico-chemical, of the direct current may be tabulated as follows:

NEGATIVE	Physiological Stimulant	Catelectrotonus. **Increased irritability** of negative pole.
	Chemical	Accumulation of hydrogen and alkalis, hydrate of calcium, potassium, sodium, and ammonium. **These form sapona-ceous matter, and are caustic alkalis.** Eschar is large, soft, and **retractile.**
	Cataphoric	Accumulation of **liquids and salts.** With mild currents promotes **nutrition.** With strong currents destroys **tissues** and has denutritive effects. **First effect is to** cause ischemia; second, **hyperemia, and** then an equalization of the circulation.
POSITIVE	Physiological Sedative	Anelectrotonus. **Diminished irritability** of the positive pole.
	Chemical	Accumulation of oxygen, **chlorin,** nitric, phosphoric, sulfuric, **and muriatic** acids. It is an acid caustic, **producing** mummifying effects. **The eschar is** small, dry, hard, and **non-tractile.**
	Cataphoric Antiseptic	Loss of fluids and salts. **Starvation of** tissues. Diffusion of **drugs in solution,** or nascent salts formed by **electrolysis of** soluble metallic electrodes.

THERAPEUTIC TECHNIQUE.

109. The direct current possesses great advantages **over** all other electric currents; for, by the aid of the absolute gal-vanometer and electrodes of specified sizes, it is possible to accurately regulate both the strength and density of the current. It is current-density that, in the application of the direct current, plays the most important rôle. It will not

suffice to speak simply of employing a current-strength of 10 milliamperes, for this can be a weak current if the surface area of the electrode is 100 square centimeters, and it can be strong if the surface area is 10 square centimeters. The whole question of current-dosage is determined by the effects one wishes to produce within the tissues or organs, and these are regulated by the density of the current and the duration of its flow. It must not be inferred from this that current-density is an exact standard of therapeutic dosage; that, for example, 1 milliampere applied through an electrode of 10 square centimeters will produce the same effects as 5 milliamperes applied through an electrode of 50 square centimeters. The current-density in both these cases is the same per unit area of electrode surface, but as the number of flux lines in the circuit with 5 milliamperes is greater than when only 1 milliampere is employed, the physiological effects will also be greater.

C. W. Müller, of Wiesbaden, makes use of an average current-density of $\frac{1}{18}$; that is, 1 milliampere to 18 square centimeters of electrode surface. Stintzing considers the limits of therapeutic dosage to lie within .5 to 50 milliamperes with an electrode surface of from 3 to 500 square centimeters. Dr. Ludwig Mann makes use of an average current-density varying from $\frac{1}{100}$ to $\frac{1}{2}$. In an application to the head he employs an electrode of 50 square centimeters with a current-strength of .5 milliampere, which gives a current-density of $\frac{1}{100}$. In cases of sciatica he employs electrodes of 20 square centimeters and a current-strength of 10 milliamperes, which gives a current-density of $\frac{1}{2}$. It will be thus seen that the dosages in direct-current applications varies very much like the dosage of drugs administered internally. There are physicians who employ currents as strong and as long as they can be employed without danger, and others who go to the opposite extreme and employ current-densities varying from $\frac{1}{500}$ to $\frac{1}{100}$. As a working basis, it may be stated 1 milliampere may be employed for each 15 or 20 square centimeters of electrode surface; that is, a current-density varying from $\frac{1}{15}$ to $\frac{1}{20}$.

In all direct-current applications to the surface of the body, the current-density is greatest in the skin beneath the electrodes;

the current-densities in the remainder of the circuit are governed by the size of the electrodes and their distances from one another and by the specific conductivities of the tissues between the electrodes. In order to employ high current-intensities, it will be therefore necessary to use large electrodes and to eliminate the irritating influences of electrolytic action in the skin by saturating the positive electrode with 4.5 per cent. sodium chlorid and the negative electrode with solutions of 5 per cent. hydrochloric acid. Of course in this arrangement, exchange of ions between the body and the electrodes takes place according to Faraday's law, but the cations introduced from the anode and the anions introduced from the cathode have no irritating effect.

110. Cerebral Galvanization.—The first requisite in applying the direct current to the brain is that the current enter the circuit slowly and gradually and that it be withdrawn in the same manner; with a good rheostat in circuit this is easily accomplished. The second requisite is that the lines of flux be symmetrically distributed in both hemispheres of the brain. As the localization of the effects of the current is almost impossible, the symmetrical distribution of the flux lines will be best accomplished by placing a large electrode composed of surgeon's gauze and block tin on the forehead and the other electrode, which is of the same composition, on the nape of the neck extending over on each shoulder. The third requisite in cerebral galvanization is that the pressure exerted on the electrodes be uniform throughout the entire application, in order to prevent fluctuations in current-strength and their disagreeable consequences— flashes of light, nausea, and vertigo. François-Franck and Mendelsohn regard galvanization of the head as contraindicated in all organic diseases of the brain and in epilepsy and only recommend its use in cerebral neuroses. On the other hand, M. Leduc, with the electrodes placed as described above, employs in hemiplegia, aphasia, and ocular paralysis, current-intensities varying from 10 to 40 milliamperes during periods varying from 10 to 20 minutes with very favorable results. As a general rule, the current-strength should not exceed

5 milliamperes and the duration of the séance should not be longer than 5 minutes.

111. Galvanization of the Spinal Cord.—The method of applying the direct current to the spinal cord will depend on whether it is intended to influence the whole length of the cord or simply some particular section of it. The general application may be either labile or stabile. In the stabile application, one electrode is placed on the cervical, or cervico dorsal, region and the other on the lumbar region. The area of the electrode will be determined by the current-strength employed. The direction of the current, whether ascending or descending, will depend on the pathological condition in the cord.

In labile applications, one electrode is stationary and the other is moved up and down the whole length of the cord, or both electrodes may be moved along the whole length of the spine, resting for 1 or 2 minutes on different sections. In applying the direct current to the spinal cord, the specific conductivity of the tissues included in the circuit, as pointed out in Art. **75,** should be remembered. When it is required to apply the direct current to a section of the spinal cord, one electrode is placed on the sternum or abdomen and the other or active electrode is placed on the desired area of the cord. When the disease is limited to a certain focus, the active electrode should remain stationary over that focus; when the disease is in the columns of the cord, as in tabes, the active electrode should be moved up and down the whole length of the cord.

Galvanization of the spinal cord is frequently accompanied by galvanization of the peripheral nerves and muscles as, for example, paralysis of the bladder, anode over lumbar region and cathode over symphysis pubes or on the perineum; in spinal impotence, anode on the lumbar region and cathode labile to the spermatic cord, penis, perineum, etc.; in stomach crises due to spinal lesions, anode over the stomach and the cathode opposite over the spinal cord.

112. Galvanization in Diseases of Joints.—The direct current is frequently employed in subacute and chronic diseases

of joints. The current should be directed through the joint. The sizes of the electrodes depends on the size of the joint and the application generally lasts from 10 to 15 minutes. The electrochemic action is desired in these cases and quite recently strong currents, 50 milliamperes, have been recommended with this end in view.

Not only have high current-intensities been recently employed in subacute and chronic joint lesions, but these same high intensities have also been employed with excellent results in the treatment of acute inflammatory joint lesions and notably in blennorrhagic arthritis. Louis Derherms, reasoning on the well-known analgetic properties of the direct current and on its vasoconstrictor action when the séance is prolonged, as pointed out by Beard and Rockwell, and on its trophic action on the nutrition of muscles, applied the direct current in the treatment of six patients suffering from blennorrhagic arthritis. In the case of these six patients the cures were absolutely without ankylosis, there was no articular rigidity and no muscular atrophy. For the shoulder and hip joints, one electrode should be placed anteriorly and the other posteriorly; for the elbow, knee, or ankle, one electrode internal the other external; for the wrist, one electrode anteriorly and the other posteriorly; for the foot and hand, one electrode is placed on the plantar or palmar surface and the other on the dorsal surface. It is absolutely indispensable to have two large electrodes; they should be longer than they are wide so as to extend above and below the articulation to include the periarticular tissues. Delherms found the Apostoli electrode (potters' clay) the most serviceable in these cases, as it could be thoroughly molded to the irregularities of the surfaces of the different joints, thus permitting equal distribution of the current and avoiding eschars. The current-intensities employed varied from 25 to 50 milliamperes and the duration of each séance was, at first, ½ hour, and after the third or fourth séance, this was reduced to 15 or 20 minutes. At first, the séances were repeated two or three times daily, to be reduced after a few days to daily applications. He gave no particular attention to polarity; however, when pain was the prominent symptom he placed

the positive pole over the area of maximum pain. As the electrodes are large and almost completely envelope the joint, care must be taken that they do not touch or cause a short-circuit. The electric applications were always commenced as early as possible from the beginning of the attack, and to this is attributed the remarkable results obtained.

In the treatment of blennorrhagic arthritis, L. Delherms recommends that: (1) The electrical applications should be instituted as early as possible and that the current-strength should be 30 or 40 milliamperes, or more, if the patient tolerates it. The séances should be repeated once or twice daily with electrodes of potters' clay. (2) The inflammatory state and the elevated temperature are in no case a contraindication for this treatment which appears to have, better than any other, the capacity to prevent ankylosis and other troubles so frequent after blennorrhagic arthritis.

113. Galvanization of Internal Organs.—The galvanization of internal organs can be accomplished either by internal or external applications. In external applications the electrodes should be so arranged that the greatest number of flux lines will pass through the diseased organ.

If a sedative effect is required the anode is placed over the painful part, stomach, or ovary, and current fluctuations should be avoided. When an irritating effect is desired the negative electrode should be placed over the diseased organs and the current may be interrupted.

In the treatment of muco-membranous enterocolitis, E. Doumer places two carbon disks, 6 centimeters in diameter, covered with several layers of chamois thoroughly saturated with tepid water in the iliac fossæ, as far as possible from the motor points of the abdominal muscles and the trunks of the crural plexus. These disks are then connected with the binding-posts of a direct-current source and a current of 30 or 40 milliamperes passed. The current-intensity is increased to 50 milliamperes and maintained at that strength for 1 minute, at the end of which time he reverses the current. The muscular contraction thus produced invariably surprises the

patient, but it is not so painful as might be supposed. If the patient does not protest, the current-strength is increased; if the patient protests, the current-strength is reduced to 50 milliamperes, and the application is continued for 10 minutes, reversing the current at the end of each minute. At the end of 3 or 4 minutes the application is much more supportable than it was at the beginning. In this way, E. Doumer was able, in the majority of cases treated by him, to employ current-intensities varying from 80 to 120 milliamperes.

From his experiences in the treatment of enterocolitis, E. Doumer arrives at the following conclusions: (1) That it is easier than one could suppose to administer percutaneously direct currents of relaitvely high intensities. (2) That these currents are absolutely inoffensive, and that the muscular contractions produced by current alternations are well supported by patients. (3) That these currents have a decided curative action in the constipation attending muco-membranous enterocolitis that was previously rebellious to all other forms of electric applications. (4) That they also have a marked curative action on the anatomic alterations of muco-membranous enterocolitis.

Special electrodes are constructed for internal applications to the stomach, colon, bladder, female genital organs, larynx, and nose. These electrodes are all made active, while the indifferent electrode is applied to the surface of the body in the neighborhood of the diseased organ. It must be borne in mind that metallic electrodes cauterize mucous surfaces very readily. When possible, the diseased organ should be filled with water so that the metallic electrode nowhere comes in contact with the mucous surfaces of the organ. In this case, the water conducts the current to the entire inner surface of the hollow viscus and comparatively large currents may be employed without danger of cauterizing the tissues.

114. Subaural Galvanization.—One electrode (5 × 5 centimeters), generally negative, is placed at the angle of the jaw against the hyoid bone, with the surface directed upwards and backwards toward the vertebral column. The other electrode is placed on the opposite side of neck between the fifth

and seventh cervical vertebræ. One electrode may also be placed on the back of the neck and the other moved up and down along the anterior border of the sternoclidomastoid muscle. The intensity of the current varies from 2 to 20 milliamperes applied from 3 to 5 minutes. It is hoped in this method by acting on the vasomotor nerves through the sympathetic to influence in a special way the circulation and nutrition of the cord.

METHODS OF GENERAL GALVANIZATION.

115. This may be accomplished in any of the following ways: (1) *General bath,* (2) *four-celled bath,* (3) *general galvanization,* and (4) *central galvanization.* For the technique of the general bath and the four-celled bath see *Technique and Physiology of Coil-Currents and Hydro-Electric Methods.*

116. General Galvanization.—One electrode, the cathode, is placed beneath the feet and the other, or active, electrode is moved over the entire body, particular attention being given to the sympathetic. The duration of the séance is usually 15 minutes.

117. Central Galvanization.—It is intended in this application to influence the entire cerebrospinal axis, and particular attention is given to pneumogastric and sympathetic nerves. One pole, usually the negative, is placed at the epigastrium and the other is passed over the forehead and vertex, along the internal borders of the sternoclidomastoid muscles, at the nape of the neck and along the entire spine. The authors of this method, Beard and Rockwell, apply to the head from 3 to 30 milliamperes, beginning with a weak current and gradually increasing until a metallic taste is perceived in the mouth. They regard the cranial center—the summit between the ears—as the most important region of the head in central galvanization. The electrode is generally applied to the cranial center for 2 minutes. From the cranial center the electrode is passed down the internal border of the sterno-clidomastoid muscle and moved up and down along this muscle for from 1 to 5 minutes. The same application is made to the opposite side.

In galvanization of the spine, special attention is given to the ciliospinal center about the level of the seventh cervical vertebræ. This center is to the spine what the cranial center is to the brain. The cervical sympathetic and pneumogastric, as well as the cord, are affected by the current. The electrode should be passed up and down along the whole length of the cord. As a rule, the back is not sensitive and from 10 to 30 milliamperes may be applied to the spine for from 5 to 15 minutes without any more discomfort than a burning prickling sensation.

TECHNIQUE AND PHYSIOLOGY
OF COIL-CURRENTS.

ELECTRICAL TREATMENT OF DISEASES.

INTRODUCTION.

VARIETIES OF WAVE-FORM.

1. Historical.—The application of electricity in the treatment of disease belongs to remote antiquity. Erb relates that Roman physicians advised their patients, in cases of paralysis and gout, to bathe in water inhabited by electric fishes in the hope that the electric discharges of these fishes would effect a cure. This shows then that long before the invention of apparatus for the production and regulation of electric currents, physicians utilized electricity as they found it in nature and recognized in it a therapeutic agent of great value in the treatment of certain diseases. The medical applications of electricity have kept pace with the scientific discoveries in the science of physics of electricity. These discoveries have placed in the hands of physicians various apparatus that enable them to regulate and dose electric energy the same as any ordinary medicament.

About the middle of the 18th century, when Otto von Guericke constructed the first electrical machine, marks the birth of electrotherapeutics. The beginnings of electrotherapeutics were difficult and the field of its application limited.

As knowledge of electrophysiology increased and as the technique of galvanism became familiar to physicians, the field of electrotherapeutics gradually extended during the years between 1800 and 1850, which are known as the *era of galvanism*.

About 1850, Duchenne published his famous work on "Localized Electrization and Its Application in Physiology, Pathology, and Therapeutics." The appearance of this work and the labors of Duchenne definitely established electric currents in medicine and surgery. He regarded the faradic current as the only form of electric energy applicable in medical practice; in France, this idea was generally adopted. In Germany, however, there was about this time, 1850, a decided reaction in favor of galvanism under the inspiration of Remak, who, in 1855, published his memoir on the method of applying the galvanic current to paralyzed muscles, in which he pointed out that the galvanic current was capable of contracting muscles when the faradic current produced no reaction whatever. Remak and Duchenne are now justly regarded as the founders of electrotherapeutics, Remak of the German school and Duchenne of the French. The controversy between these great teachers is of the most interesting kind and served to render clear many obscure points and to attract the attention of scientific men to the medical applications of electricity. Remak and Duchenne were both right in recommending the current that each so carefully studied, but they were wrong in recommending it to the exclusion of all others.

2. It is the duty of the electrotherapeutist to select from the various electric currents that one which is best adapted to the case in question and to so apply it as to bring about the surest and quickest cure. In the early days of electrotherapeutics little distinction was made between different varieties of electric currents, the common belief being that it was mainly a question of getting electricity somehow into the body and of less importance by what means this was accomplished. Though such crude notions even today are common among the laity, the medical profession has learned that the sources employed for sending an electric current through the body are

of the first importance, and that it is not sufficient to know that electricity is actually traversing the human organism but that the qualities of the current must also be taken into consideration. Whether the treatment is beneficial or not depends, in some cases, on the direction in which the current flows, and, in others, mainly on the strength together with direction, and also in many cases on whether the current is continually flowing in one direction or is interrupted or alternating.

We have already stated in this Course that it is not supposed that different classes of electricity are in existence. Whatever is the fundamental nature of electricity, it is understood that it does not undergo any change whether it issues from a primary cell or static machine. In either case the nature of the electric pressure that causes the current to flow is the factor that determines its suitability for this or that treatment. In the study of the physiological effects of any electric current, the physical characteristics of the electric wave that traverses the tissues explain the effects produced by that current and permit an accurate appreciation of the relation of cause and effect in electrotherapeutics.

3. **Direct Continuous Currents.** — In order to show fully the function of wave-form or pressure when considering the properties of an electric current, the main varieties will here
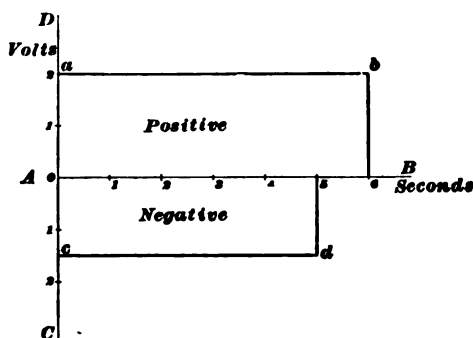
FIG. 1.

be illustrated by means of diagrams. Let the line *A B*, Fig. 1, represent the zero-line of pressure and also the line along which the duration of pressure is indicated in seconds, *1, 2, ... 6.*

Along the line *CD* the pressure, in volts, is measured off, beginning at the zero-point *O*. Distinction is made between positive and negative pressures, these two acting in opposite directions; if positive, the pressure is laid off along the line *A D* above the zero-line *A B*; if negative, along the line *A C* below the zero-line.

When a current of 2 volts acts for a period of 6 seconds in a positive direction, it is represented by the line *a b*. Again, if
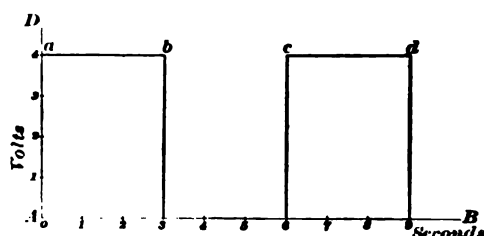
FIG. 2.

a current of 1.5 volts flows for 5 seconds in a negative direction, it may be shown by means of the line *c d*. In one case the pressure is above, in the other below the zero-line *A B*. When a current, as in either of these instances, is continually flowing in one direction it is called a **direct current,** and if its pressure is constant, a **continuous current.**
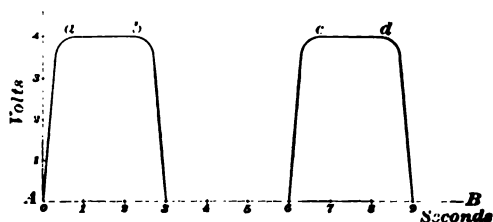
FIG. 3.

In the example here given, the currents are both direct and continuous.

4. Direct Interrupted Currents.—A current may be direct but not continuous, as shown in Fig. 2. Here a current flows for a period of 3 seconds under a pressure of 4 volts, as indicated by means of the line *a b*; then the pressure suddenly falls to zero along the line *b 3* and the current ceases. This

interruption lasts for a period of 3 seconds, when the pressure again suddenly rises to its former value and remains there for another 3 seconds, after which it falls to zero. A current of this class is called a **direct interrupted current.** It is rarely the case that these changes in pressure or flow take place as suddenly as indicated in these diagrams; usually they assume more the form of a wave, as shown in Fig. 3, where the pressure neither rises nor falls instantaneously, but requires a certain time to reach its maximum and minimum value.
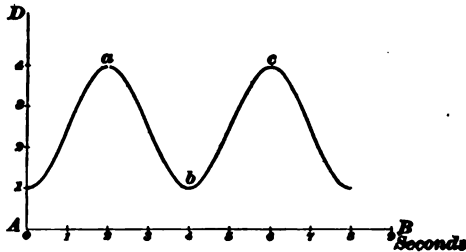
FIG. 4.

5. Pulsating Currents.—A current may vary in pressure or rate of flow without necessarily falling to zero. An example of this class is shown in Fig. 4. Here the pressure periodically rises from 1 to 4 and falls from 4 to 1 volts. Such a current is called a **pulsating current.** A peculiar variety of the pulsating current is that produced by means of a static machine. In this instance it is a question of charges of very high potential that periodically pass over an air-gap before they reach the human body. These charges collect in the static machine until they are of a potential sufficiently high to bridge the air-gap. The pressure falls and again rapidly rises many times per second. Fig. 5 represents a pulsating current of this class.
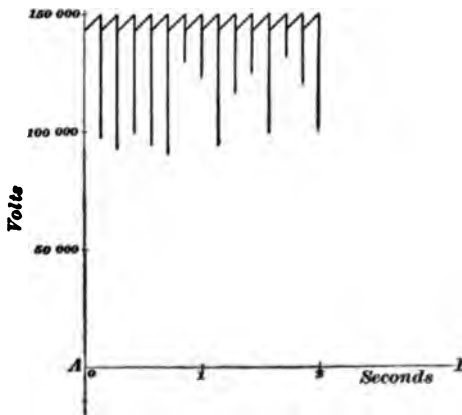
FIG. 5.

The graphic representations of these four types of direct-current flow illustrate very clearly the physical characteristics of each, and these different physical characteristics account for the different qualities of the direct current and explain their different physiological effects, as described in *Technique and Physiology of Static and Other High-Frequency Currents*, and also in *Technique and Physiology of Direct Currents*.

6. Alternating Currents.—The pressure of an electric current may not alone fall to zero, as shown in Fig. 2, but may fall periodically below zero and thus exert a pressure in the opposite direction; it becomes then an **alternating current**.
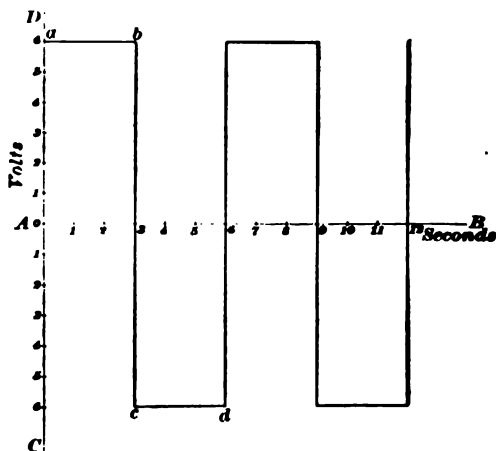
FIG. 6.

Such variations in pressure are shown in Fig. 6. The current begins to flow at a pressure of 6 volts for a period of 3 seconds, indicated by the line *a b*, after which it not alone falls to the zero-line at 3, but below this to a point *c* representing a pressure of 6 volts in a negative, or opposite, direction. This pressure has also a duration of 3 seconds, represented by the line *c d*, after which the pressure falls to zero, changes direction, and again rises to a value of 6 volts.

Like the direct interrupted current, the alternating current does not change in the abrupt manner shown in Fig. 6, but

assumes more of the wave-form illustrated by Fig. 7. This corresponds somewhat with the wave-form that the commercial alternating current assumes, a wave-form that is called *sinusoidal* for reasons given in *Direct Currents*.

When the wave-forms are alike on both sides of the zero-line they are said to be *symmetrical*. The waves illustrated in Figs. 6, 7, and 8 are symmetrical. When the wave-form is not the same on both sides of the zero-line, as shown in Fig. 9, the waves are *dissymmetrical*. In these forms of symmetrical alternating-current waves each succeeding wave is supposed to equal the preceding one both as to magnitude and form.
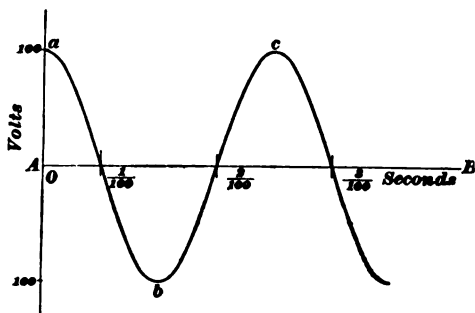
FIG. 7.

7. Dissymmetrical Waves.—To the class of **dissymmetrical waves** belong those produced by the faradic coil.
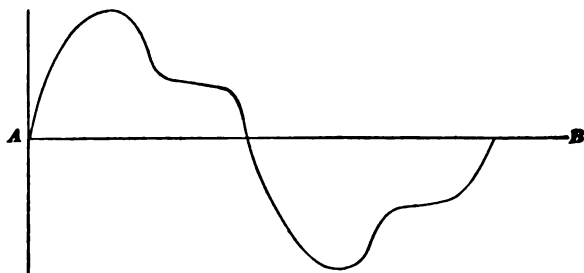
FIG. 8.

In order to fully understand why these waves are dissymmetrical and why they are different both as to their nature and effects from those of the ordinary sinusoidal waves, it will be necessary to investigate their primal cause. As will be remembered from the explanations given in *Magnetism and*

Electromagnetism, a current from a primary battery is sent through the primary coil of the faradic apparatus and the current is then periodically interrupted by means of a vibrating spring that alternately opens and closes the circuit. That this current through the primary coil must be interrupted in order to operate the coil is obvious, as an E. M. F. is induced in the secondary coil only when changes take place in the primary-current flow or when it is stopped or started. It might be
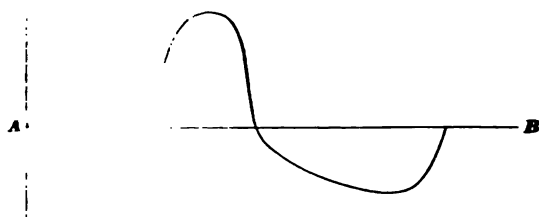
FIG. 9.

supposed that every time the primary current is started or stopped an inductive wave of equal magnitude is sent through the secondary coil and that here E. M. F.'s of equal strengths but alternately acting in opposite directions would be produced. But this is not the case, as will be shown by means of the following diagrams.
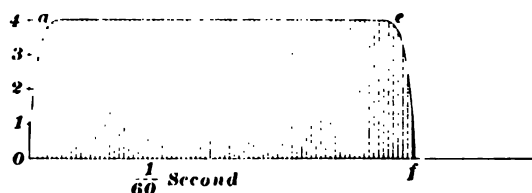
FIG. 10.

Let it be supposed that a current of 4 volts, Fig. 10, is sent through the primary coil. We will assume that this current rises from 0 to its maximum value at a, remains there for the time of $\frac{1}{60}$ second, when it, at e, decreases in value, and falls to zero at f. During the rise in pressure from 0 to a and the decrease in pressure from e to f the secondary coil would have

E. M. F.'s induced in it, and these are represented by means of
Fig. 11. Here the negative wave *0 a b* would be the one induced
by the rise in E. M. F., shown at *0 a*, Fig. 10, and the other
wave *c d e* a result of the decrease in E. M. F., shown at *e f*,
Fig. 10. Both of these waves are here represented as being
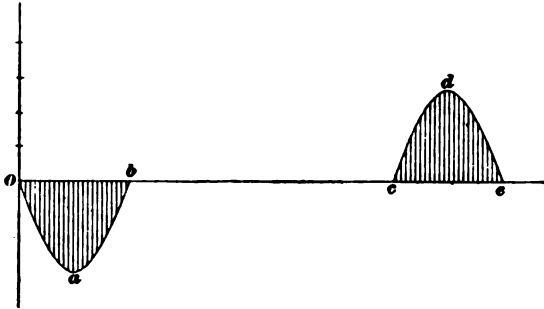
FIG. 11.

equal in magnitude and duration. In reality they are not so,
for the reason that the primary wave is not of the form shown
in Fig. 10, but more of that given in Fig. 12. We see here that
the E. M. F. does not rise at once to its full value of 4 volts, but
after reaching the point *a* it only gradually reaches the point *b*.
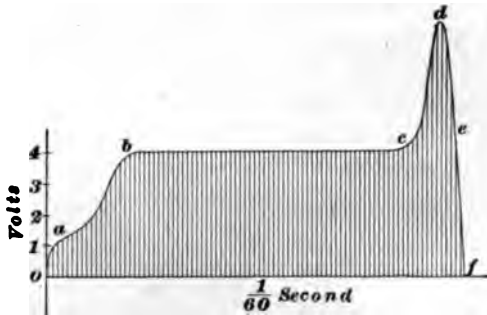
FIG. 12.

This is caused by the self-induction of the primary coil. The
result of this gradual increase is that the negative wave in the
secondary coil, shown at *0 a b*, Fig. 13, will be of a relatively
longer duration but also of a smaller E. M. F. Next it is noticed
that the primary-current wave does not fall at once to zero, as in

Fig. 10, but, as shown at *c* in **Fig. 12**, begins to rise un point *d* is reached, after which it falls along the line *e f.* is also a result of the self-induction of the primary coil, i.
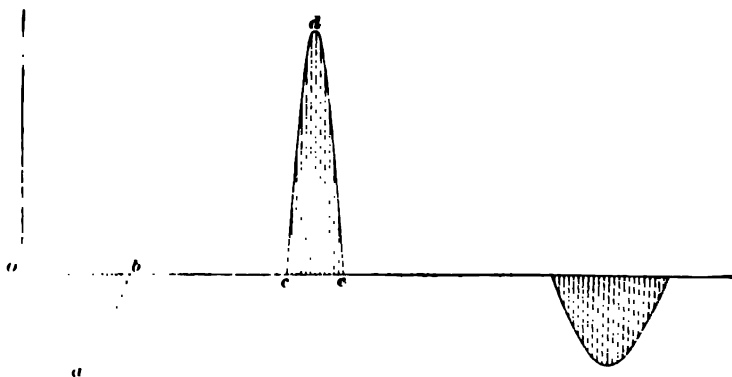
Fig. 13.

in-tance producing the so-called extra-current. **This enlarged** current wave in the primary coil, will cause a similar wave in the secondary coil, but the increase in height will be counterbalanced by a decrease in duration, as seen at *c d c*, Fig. 13. We see then, that on closing the primary circuit a small negative wave of relative long duration is produced in the secondary coil, and that on breaking the primary circuit, a higher positive wave but of shorter duration is the result.

8. Another feature, illustrated in Fig. 13, that should receive some attention is the interval between the waves *0 a b* and *c d c.* Ordinarily, it is supposed that these waves are so connected that
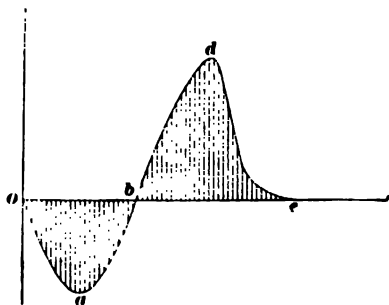
Fig. 14.

the closing wave *0 a b* proceeds directly into the opening wave *c d c* without any intervening space, as indicated in Fig. 14. Extensive experiments performed by Bordier tend to prove that

such is not the case and that, in fact, there is a considerable
interval between the waves of "make" and "break." As long
as the current-strength remains constant, as for instance, between
the points *b* and *c*, Fig. 12, no effect is produced on
the secondary coil, and an interval of rest is therefore
indicated between the points *b* and *c*, Fig. 13. It is ordi-
narily supposed that while these intervals may be found
between the make- and break-waves in relatively low frequen-
cies, when it comes to higher frequencies such intervals no
longer exist, and that in such cases the closing wave *O a b*
proceeds directly into the opening wave *c d e* without any
intervening space, as already indicated in Fig. 14.

Bordier bases his experiments on previous investigations by
Blaserna, who found that the durations of the make- and break-
waves to which the secondary coil is subjected are .00048 and
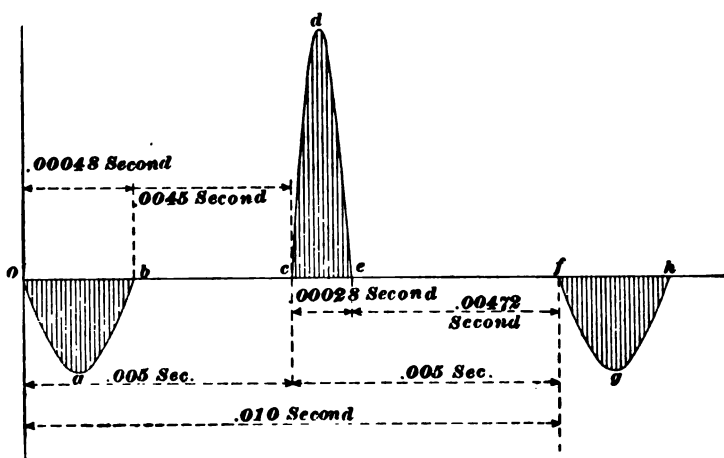
Fig. 15.

.00028 second, respectively. (See Fig. 15.) Knowing these two
values it is possible to calculate the intervals between make and
break as well as between break and make. Bordier takes as an
example an interrupter moving at the rate of 100 vibrations per
second, each complete vibration therefore occupying a time of
.01 second. The durations of the several waves and the
interval between them is then represented by means of Fig. 15.

The make-wave Oab has, as already stated, a duration of .00048 second and the break-wave cde one of .00028 second. Bordier then claims that the beginning of the latter wave, that is the point c, occupies a middle position between the starting points O and f of the two make-waves. The distances Oc and cf will therefore each correspond to half the time of one complete vibration, or .005 second. By subtracting the time consumed by the make-wave from this time of .005 second we find .005 — .0005 = .0045 second to be the interval of time between a make- and break-wave. In the same manner by subtracting the time of the break-wave, that is .00028 second from .005 second, the time interval between the break- and make-waves is found to be .005 — .00028 — .00472 second.

It should here be noticed that the *quantities* of electricity represented by the make- and break-waves are alike; the surface area covered by either wave Oab and cde should therefore be the same. When thus the make-wave requires about double the time to send the same quantity of electricity through the coil as the break-wave, it is clear that the rate of flow, that is the amperage, must, during the flow of the make-wave, be half the value of the break-wave.
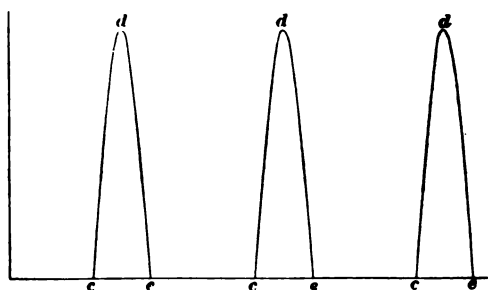
Fig. 16.

The waves of break being of a so much higher E. M. F., their effects on the human body are often so predominant that the waves of make may be left out of consideration. In that case, the active part of the faradic current may be represented somewhat as in Fig. 16, which consists simply of break-waves.

9. Besides these fundamental wave-forms, each of which is produced by a simple elementary source of E. M. F., the indications in therapeutics frequently require a combination of 2 wave-forms, as, for example, the galvanic current with the
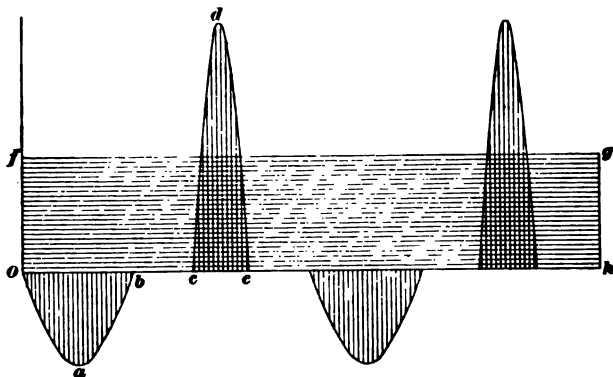
Fig. 17.

faradic or the galvanic current with the sinusoidal current. The excitatory neuromuscular effects of the faradic current are frequently indicated in conjunction with the electrolytic and
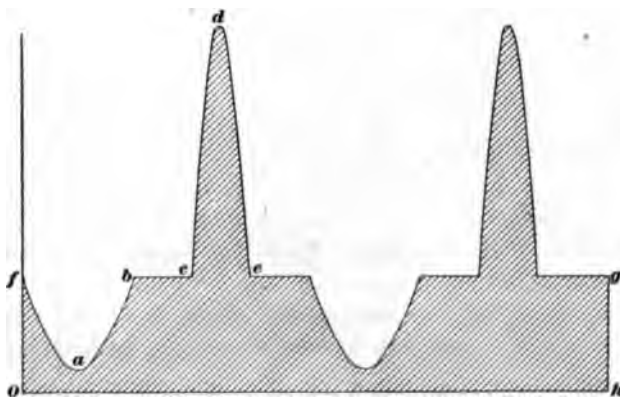
Fig. 18.

cataphoric properties of the direct current, in which case the faradic coil is placed in series with a direct-current source. The current resulting from this combination has a pressure equal

to the sum of the pressures of both currents; further, the quan-
tity of electricity traversing the tissues is much greater than
with the faradic current alone. For these two reasons the effects
of galvano-faradization will be more intense than those of fara-
dization alone.

In Fig. 17, the curves of a galvanic and faradic current are
superimposed on each other, *O f g h* representing the galvanic
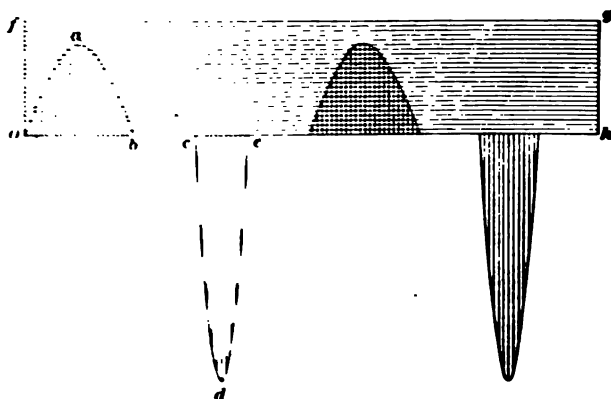
FIG. 19.

and *o a b*, *c d e* the faradic current. The galvanic current acts in
a positive direction similar to the break-wave *c d e*, to obtain
which result the anode of the galvanic current is connected with
the cathode of the faradic current. The result of this combina-
tion is shown in Fig. 18, where the E. M. F. of the galvanic
current *O f g h* is decreased at *f a b* by the negative wave *O a b* of
the faradic current and increased at *c d e* to an amount corre-
sponding to the height of the positive faradic wave *c d e*. Where
these waves do not act, the galvanic current retains its original
E. M. F.

If the anode of the direct current is connected with the anode
of the faradic current, both E. M. F.'s will act in opposition,
and the resulting wave-form, as well as the physiological effects
within the tissues, will not be the same. In Fig. 19, the
galvanic and the faradic currents are so combined that the

break-wave *c d e* of the latter works in opposition to the galvanic current *O f g h.* The results of this combination are shown in Fig. 20, where it is seen that at *f a b* the make-wave of the faradic is superimposed on the galvanic current, and at *c d e* the
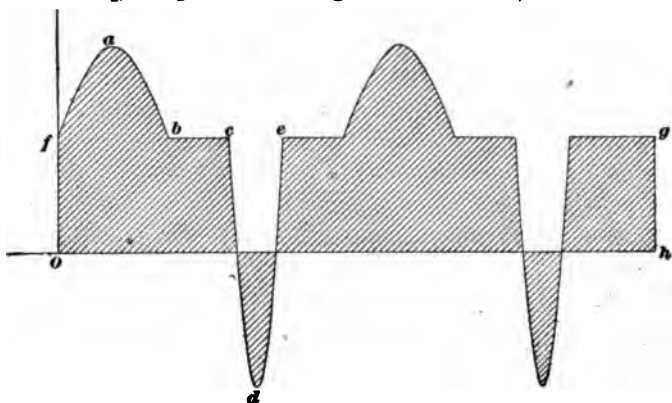
FIG. 20.

break-wave not alone reduces the galvanic current to zero, but for a short period changes the direction of the current.

Even when the E. M. F.'s of the break-wave should happen to equal that of the galvanic current, it is seen that the current is not constantly zero, but only periodically so on account of
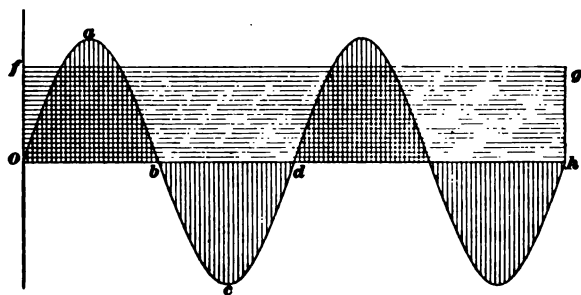
FIG. 21.

the physical characteristics of the faradic wave. It will be necessary, therefore, to be careful in combining both currents and to see that in order to obtain maximum effects the anode of the galvanic current is connected to the cathode of the faradic current.

10. When the indications require it, the galvanic current may be combined with the sinusoidal current, producing the galvanosinusoidal current. These two forms are shown combined in Fig. 21, in which the line *O h* is the zero-line and the
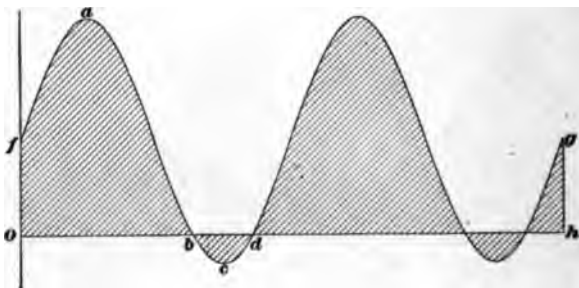
Fig. 22.

line *f g* the galvanic current, while the waves *O a b c d* represent the sinusoidal current. It is clear that the positive direct current will increase the size of the positive waves and act in opposition to the negative waves, and thereby reduce the size of the latter. The result will be the wave-form shown in Fig. 22. Currents of this class are called galvanosinusoidal currents.

In the case of the sinusoidal alternating-current waves, each such succeeding wave is supposed to equal the preceding one both as to magnitude and form. There is also a source of electrical pressure
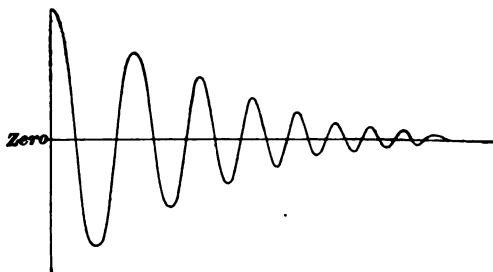
Fig. 23.

where this is not the case and where each current impulse consists of a series of waves gradually decreasing in size. Currents of high frequency act in this manner, as shown in Fig. 23.

11. Changing a Direct Into an Alternating Current. It is not absolutely necessary to have an alternating-current source in order to subject a patient to a current of that character. By means of suitable appliances it is also possible to change any

direct current into one that is alternating. In a crude way this may be accomplished by means of the pole-changer, shown in Fig. 34, *Accessory Apparatus.* By moving the handle H alternately to the left or right, the current will periodically change its direction through the two binding-posts E_1 and E_2. This method is limited only to cases where the interruptions take place relatively slowly, and are continued only for short periods. When these interruptions are of a more rapid nature and must be carried on for a greater length of time, it is necessary to have means that will replace the operator's hand and carry on the function automatically. Various means may be used for this purpose; usually it is a clockwork in some form,
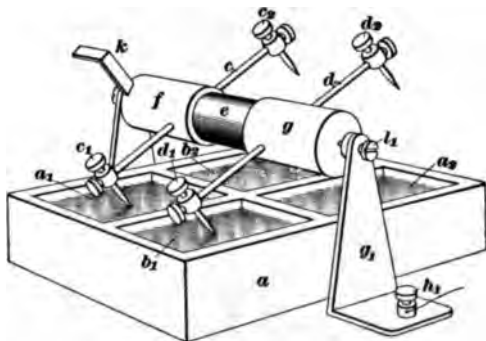
FIG. 24.

which, after being wound up, will run for a time and at regular intervals interrupt and reverse the direction of the current. A pendulum with an adjustable weight will determine the number of interruptions per minute. It is unnecessary here to explain this part of the apparatus in detail; only those parts that accomplish the current reversals will be considered.

A device of this kind is shown in Fig. 24 in perspective, and in Fig. 25 in outline, in addition to the various electric connections. The vessel a is divided into four compartments a_1, a_2, b_1, b_2, each of which is filled with mercury and is connected, in the manner shown in Fig. 25, with a direct-current source. Over the central part of this vessel is located an ebonite rod e with the caps f, g, which are supported by the points of

the screws l_1, l_2 in a manner that will allow them to oscillate freely. Through the caps project rods c, d, which at their extremities carry the adjustable pins c_1, c_2, d_1, d_2. If the bracket k is connected with some oscillating device, such as a pendulum of a clock or a metronome, the rods c, d will also oscillate and simultaneously dip either the pins c_1, d_1 or c_2, d_2 into the mercury of their respective compartments. While dipping into the mercury, an electric contact is established; a current will pass through the pins and rods, the direction of which will depend on the polarity of the respective compartments. The period of contact will depend on the extent to which the pins are inserted in the liquid, and this again will depend on how the pins are adjusted relative to their supporting rods.

The connection between the primary-current source and this device is shown in Fig. 25. A primary, or storage-, battery o with the required number of cells has its positive conductor o_1
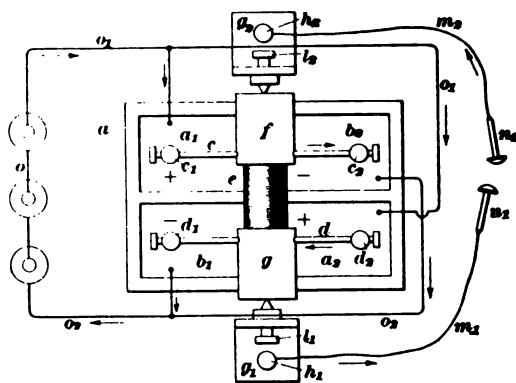
FIG. 25.

connected with compartments a_1, a_2, and its negative conductor o_2 with the compartments b_1, b_2; the former will therefore always remain positive and the latter negative. When the pins c_2, d_2 dip into the compartments b_2, a_2, the latter will send a current through rod d in a positive direction, while the return current will pass through the rod c to compartment b_2 back to the battery, provided the rods are, as will be shown further on, in electric connection with each other. As the cap g is insulated

from f by the ebonite rod e, the current is prevented from passing directly to f and will be compelled to go through screw l_1 to bracket g_1 into the binding-post h_1, from which it goes into the conducting-cord m_1 to electrode n_1. After passing through the patient, it returns again through the other electrode n_2 and cord m_2 to binding-post h_2, bracket g_2, screw l_2, cap f, and rod c to the compartment b_2.

When the pins c_1, d_1 dip into the mercury, c_1 will be made positive and d_1 negative and a current will be sent through the circuit in the opposite direction. Such reversal will take place for each beat of the pendulum, and the number of reversals per minute may be regulated by adjusting the active length of the pendulum.

In place of devices where the interruptions are produced by means of oscillating parts, there may be used some that consist of rotating cylinders combined with contact-brushes. A device of this kind is shown diagrammatically in Fig. 26 (a) in which h is a cylinder of some insulating material, such as ebonite, that is covered with metal segments of a peculiar form. This cylinder may be set in rotation by connecting the pulley g with some motor. The positive terminal of the primary battery d connects through conductor d_2 with the brushes e_1, e_2, and the brush e_2 through conductor d_1 with the negative terminal; the segments a, c will therefore always be positive and b negative. Two other brushes f_1, f_2 transmit the current from those segments with which they momentarily engage to the patient's circuit r. After the cylinder h has made half a revolution it will occupy the position shown in Fig. 26 (b). The segment b has now moved out of contact with brush f_1 and segment a occupies its place. The brush f_1 has therefore had its potential changed from negative to positive, and as the other brush f_2 is brought into contact with the segment b, it has simultaneously changed from positive to negative. Consequently, the current through the patient r has been reversed in direction, as indicated by the arrow. The current is reversed twice for each revolution of the cylinder, and the reversals per minute will depend on the revolutions per minute.

In the present position of the brushes f_1, f_2, it is seen that the

interval during which the circuit is broken between each
reversal is very short.   The length of this interval will depend
on the distance between the points a_1, b_1, and b_1, c_1, respectively,
which are the places where the brush leaves one segment to make
contact with the one following.   By increasing this distance
and decreasing the active part of the segment, it will be possible
to decrease the period of contact to a minimum.   For this reason
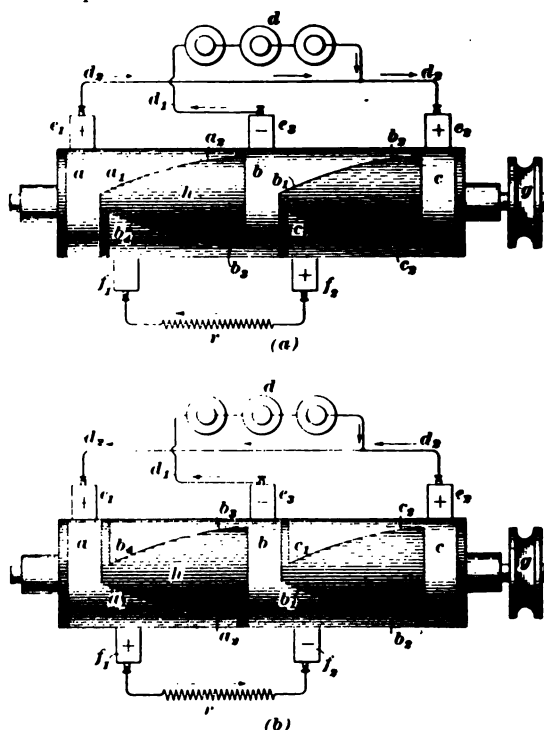
Fig. 26.

the three segments have been contracted to a narrow strip at the
points a_2, b_2, b_3, c_2.   To be able to vary this interval of current
interruption in the patient's circuit, the brushes f_1, f_2 are so
placed that they can be simultaneously moved to the right or
left and thus be made to occupy any position that will give the
necessary interval.   For instance in the position indicated, the
interval of break may be one-twentieth the interval of contact,

while if placed at b_3 the brush may make contact for a period corresponding only to one-twentieth that of the break.

The difference between the two varieties of current-waves that will result from this varied position of the brushes is clearly shown in Fig. 27. It is supposed that the whole circumference of cylinder h, in Fig. 26, is divided into 20 equal parts. If the interval a_1 b_4 be one-twentieth of the total circumference, and there is another interval equal to this on the rear of the cylinder, there remain 18 divisions to be divided among two segments, which leaves 9 divisions per segment. This means that for nine-tenths of each half revolution each of the segments a, b, and c will make contact with the brushes f_1, f_2. In Fig. 27 (a), the line $A B$ is divided in 20 parts, cor-

FIG. 27.

responding to the divisions mentioned, and the voltage indicated along the line CD. The beginning of the wave a at a_1 may, for instance, correspond to the moment when the segment a comes in contact with the brush f_1 at a_1, Fig. 26 (b). The pressure is seen to remain constant for a period corresponding in length to that required by the cylinder for making $\frac{9}{20}$ revolution, then the pressure suddenly drops to zero at a_1 and remains there for $\frac{1}{20}$ revolution. At the point b_4, corresponding to b_4, Fig. 26 (b), contact is made with the point b_4 of segment b, which is of negative potential. The current is therefore sent in a reversed or negative direction through the brush f_1. This is represented by the wave b beginning at b_4. Again the current flows steadily during $\frac{9}{20}$ revolution, at the completion of which the pressure
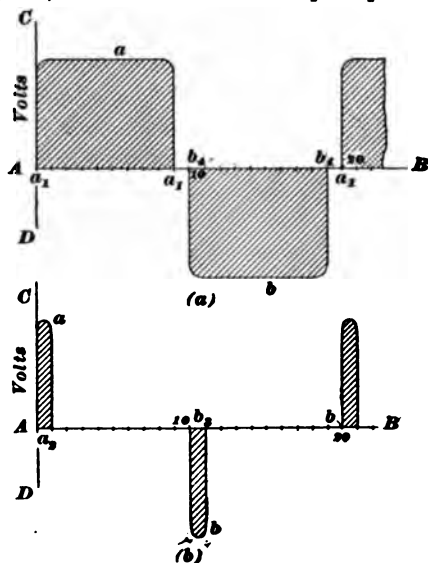
again falls to zero at b_4; another interruption occurs and then a repetition of the wave a begins.   When the brushes are moved to the right and minimum contact is made, the results are as represented in Fig. 27 (b); the parts a_2, b_3, b_2, c_2 of the segments are of a width corresponding to one-twentieth the circumference of the cylinder, and the current-waves sent by them through the brushes are represented by the waves a, b. Why this is so will now be clear to the student and will require no further explanation.   It is obvious that by placing the brushes half way between these extreme positions, a place will be found where the durations of the waves are the same as those of the intervals.

Having given this brief description of the wave-forms of the different currents used in medicine and surgery, we believe the student is better able to comprehend the physiological effects of the currents to be discussed in this section, namely: (1) The *faradic current;* (2) the *sinusoidal current;* (3) combinations of these currents with the galvanic current, that is, the *galvano-faradic current* and the *galvanosinusoidal current.*

FARADIC CURRENTS.

INDUCTION-APPARATUS.

12.   Induction-apparatus may be classified as follows: (1) Volta-faradic apparatus, or physician's induction-coil; (2) magneto-electric machine; (3) sinusoidal machine; (4) alternating dynamo.   All the induction-currents employed in electrotherapeutics, with the exception of the primary coil-current of the physician's induction-coil or faradic apparatus, are to-and-fro, or alternating currents.   They are also currents of comparatively high voltage, as compared with the direct currents, but with very little quantity.

Of all the apparatus employed in electrotherapeutics, the physician's induction-coil has been the most used and is, even today, the most widely known.   Many physicians still believe that the induction-coil constitutes the whole, or at least the

major part, of electrotherapeutic apparatus, and for them the application of electric energy in medical practice is a synonym of faradization. The induction-coils so frequently used in the past were of small dimensions, both for the purpose of economy and to be easily portable. On account of their small dimensions, it was necessary, in order to produce sufficient energy, to use very fine wire; consequently, the current they produced was of very high tension and little or no quantity. These coils were used to produce energetic muscular contractions without regard to their sensory effects or their effects on the spinal centers. They were provided with but a single interrupter, which was too rapid for the production of physiological contractions, and too slow, jerky, and irregular for the production of sedative effects in painful conditions. The apparent simplicity of their action accounts also for their widespread use. This simplicity of action is, however, only apparent; for, of all means of electric excitation the physician's induction-coil is the most difficult to determine its exact value, as regards the effects produced by it.

The faradic current is derived from the physician's induction-coil, which should be regarded as a transformer, because by means of its interrupting device and its coils of wire it transforms a direct current of relatively low voltage and high amperage from voltaic cells, storage-batteries, or direct-current dynamo into an induced current of high voltage and low amperage. The coil-apparatus from which the faradic current is derived consists essentially of the following parts: (1) Direct-current source, which may be voltaic cells, storage-batteries, or direct-current dynamo; (2) the primary coil with its core of soft-iron rods; (3) the vibrator; (4) the secondary coil; (5) the condenser.

13. Current Source for Primary Coil.—The primary of the induction-coil may be actuated by the direct current of 110 volts with a 32-candlepower lamp in series with the source, Fig. 28. When using the commercial current to actuate the primary, the coil should be provided with a condenser or the interruptions of the current will not be instantaneous.

Physicians who have the 110-volt direct current in their office may utilize it for the following purposes:

1. For galvanic and electrolytic applications by placing a 10-candlepower lamp in series with the source and a variable resistance in shunt with the patient.

2. For actuating the primary of an induction-coil by placing a 32-candlepower in series with the source.

3. It may be utilized as a source of light and cautery and also to actuate the primary of a Ruhmkorff coil for the production of high-frequency currents or X-rays.

11. Faradic Coil Actuated by an Electric-Light Circuit. Though a faradic coil generally is actuated by means of primary or secondary cells it is sometimes convenient, when a light circuit is at hand, to let the coil as well as all other
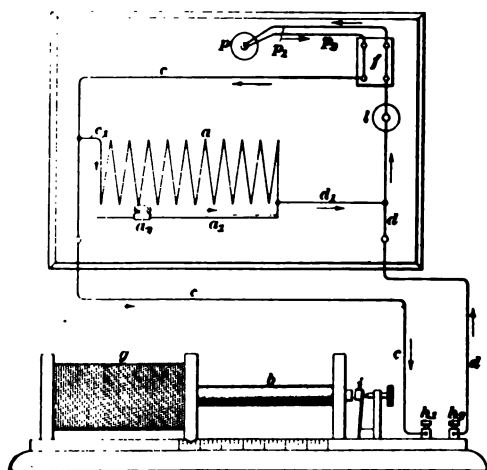
Fig. 28

apparatus be operated by means of same, and in this manner do without primary cells entirely. The main point is to find suitable means whereby the voltage of the light circuit may be regulated to suit the various requirements. Fig. 28 shows an arrangement by means of which this may be accomplished.

An incandescent lamp is removed from one of the ordinary wall sockets and a plug p inserted in its place. Conductors

p_1 and p_2 lead from this to the safety fuse f, whence the conductors c, d go to the binding-posts h_1, h_2, which connect with the primary coil b and interrupter i, respectively. The latter may be of any form that will give the desired number of vibrations per minute. An incandescent lamp l of 32 candle-power is inserted in the circuit; as this lamp has a resistance of about 110 ohms, it will in a circuit of 110 volts allow a current of only 1 ampere to flow. With no further additions to the circuit, a current of this strength will pass constantly through the primary coil and no regulation of the current-strength will be possible; a rheostat a is, therefore, connected to the circuit by means of conductors c_1, d_1, a contact a_2, movable along the bar a_1, enabling the operator to adjust the amount of resistance included in the circuit. Connected in this manner the rheostat is in parallel with the primary coil, and the current that flows through either will depend on their relative resistances. The resistance of the primary coil being constant, the current-strength through same must be controlled by means of the rheostat. If the contact a_2 of the latter stands at the extreme left, the whole current flows through the rod a_1 because all the resistance is cut out; consequently the coil b will receive no current. When the contact a_2 is moved to the extreme right, the whole resistance of the rheostat is inserted and the current that flows through the coil b will depend on the relation its resistance bears to that of the rheostat. For instance, if the total resistance of the rheostat a is 10 ohms and that of the primary coil 3.25 ohms, the current through the latter will be .732 ampere. If the rheostat resistance is adjusted so as to equal that of the primary coil, viz., 3.25 ohms, then the current will divide equally between the two and will be reduced to .493 ampere through the coil.

The fuses serve the purpose of limiting the current-strength through the circuit to that of 1 ampere. They are so made that if the line voltage should for some reason increase and send a heavier current through the coil-circuit, the fuse will burn out and break the connection of the primary coil with the main circuit. The current-strength through the secondary circuit is adjusted in the usual manner, either by means of the movable

... ̣ary ... ̣ ̣, ... by means of a rheostat, which in conjunc-
... ̣ ̣ w ... ̣ that ... the primary circuit will enable the operator to
... ̣ ... ̣ ... of suitable strength through the patient.

... ̣ ... ̣ ... ̣ current is not available, chemical cells may be
... ̣ ... ̣ ... ̣ating the primary coil. These cells may be of
... ̣ ... ̣ ... ̣ type, or they may be dry cells such as the
V ... ̣ ... ̣ ... ̣ A very good cell, on account of its high
... ̣ ... ̣ durability, is the Hydra cell. Two or three
... ̣ ... ̣ ... ̣ted in series are sometimes used for supply-
... ̣ ... ̣ ... ̣ the faradic apparatus; it is claimed that they
... ̣ ... ̣ ... ̣ results. For a portable faradic apparatus
... ̣ ... ̣ ... ̣ is the most serviceable and convenient.

15. ... primary coil, with its interrupter and core of
... ̣ ... ̣ ... ̣ the galvanic current from the chemical
... ̣ ... ̣ ... ̣ current with the higher voltage and lower
... ̣ ... ̣ What is shown as the *extra*, or *primary*, current is
... ̣ ... ̣ ... ̣ from this coil. It is unidirectional,
... ̣ ... ̣ ... ̣ current. Its voltage is higher than that of
... ̣ ... ̣ ... ̣s, and the amperage of its sepa-
... ̣ ... ̣ much higher, but of short duration. There
... ̣ ... ̣ any ... ̣ ̣-posts on faradic batteries, from which
... ̣ ... ̣ ... ̣ taken and applied in medicine. The
... ̣ ... ̣ ... ̣ remember is that this primary current is not
a galvanic but an interrupted induced current with a higher
voltage and higher amperage than the cells in circuit. It has a
marked polarity, which may be readily tested by holding large
well-moistened electrodes in the hands. In using the primary
current percutaneously, large well-moistened electrodes are
employed to cut down cutaneous resistance. This compensates
for the low voltage and facilitates current penetration. The
power of any current to penetrate tissues depends on its
E. M. F. and the resistance of its circuit.

16. The **vibrator** is a vital part of every faradic apparatus.
Without it there would be no current. On its smooth and even
action, on the rapidity and slowness of its movements, depends
much of the therapeutic work of coil-currents. There should be
at least two adjustable vibrators—one for rapid vibrations, the

other for slow. Slow vibrations include from 50 to 150 periods per minute, giving the muscle time to rest between each alternate contraction and relaxation. The slow vibrator may be adjusted so that it gives from 200 to 2,000 periods per minute, producing muscular massage. The rapid vibrator should be capable of attaining a maximum rate of from 12,000 to 20,000 periods per minute. To do good work, they must receive careful attention. They must be well polished, thoroughly freed from oxids present, and always kept in good working condition. Starts and jerks in the vibratory movement are very often unpleasant and sometimes harmful, and are always to be attributed to imperfect mechanism or to want of proper attention on the part of the operator. A single non-adjustable vibrator does not belong to the faradic apparatus employed in modern therapeutics. Such a vibrator is of little use in the treatment of disease. When the indication for treatment is to procure sedation, a vibrator that is slow, jerky, and irregular does harm. To obtain the best sedative effect, the interruptions should be rapid (15,000 to 20,000 a minute), perfectly smooth, even, and regular.

The physician should thoroughly understand the working of the vibrators of his faradic coil. The manner in which the vibrators work is reflected in the wave-form of the coil-current, and on the wave-form depend the therapeutic effects on nerve and muscle of the current from the faradic coil. One wave of the secondary induced current is caused by the variation in the intensity of the appearing magnetic field due to the interrupter closing the primary circuit. The other wave of the secondary induced current is caused by variation in the intensity of the magnetic field due to the interrupter breaking the primary circuit. For each oscillation of the interrupter in the primary circuit there are produced two induced currents in the secondary—one inverse at the moment of contact and the other direct at the moment of break. These two induced currents are equal in quantity, but they differ in tension, due to the fact that they are not formed with the same rapidity; the greater E. M. F. corresponds to the current of rupture. Both are due to fluctuations of the primary current; but this

fluctuation is extremely short for the opening current in the primary circuit and is much more prolonged when the circuit is closed in the primary. The manner in which the potential increases and decreases, influences sensation and motion irrespective of the degree of the potential or the rapidity of the alternations. Sensory and motor nerve- and muscle-fiber can respond in a manner peculiar to each of them when subjected to electric excitations to the number of from 6,000 to 10,000 per second. The lower frequencies and potentials have an exciting and irritating effect, while the higher frequencies and potentials have a quieting and sedative effect. From these considerations it must appear clear how important a position the rapidity and regularity of the oscillations produced by the vibrator occupy in therapeutic results.

17. Testing Vibrators.—The vibrator spring and platinum tip should be thoroughly brightened. As the vibrator is in the primary circuit, in studying the qualities of its movements the secondary coils are not considered. Each degree of E. M. F. in the primary acts efficiently through an air-gap of certain length: If the air-gap is too short the current will be too heavy and will rapidly destroy the interrupter; if the air-gap is too long, there will be no current. The physician should therefore practice regulating the spark-gap to correspond to the E. M. F. in the primary circuit. He should practice adjusting the vibrator for all variations in the E. M. F. from the fraction of 1 volt to 6 or 8 volts, or the maximum current-strength available in the primary circuit.

The physician should first study the finest adjustment possible with the vibrator on his faradic coil. By the finest adjustment is meant that length of air-gap between the vibrator spring and the platinum tip through which the current of the smallest E. M. F. will actuate the vibrator. Having secured this adjustment by repeated manipulations of the platinum tip and primary-current rheostat, he should study its sound through the telephone receiver and also observe closely its color and character. When the physician is thoroughly familiar with the finest adjustment for minimum voltage, he should practice the

same adjustment for all degrees of voltage available in
the primary circuit. Practice of this kind will quickly render
him master of the interrupter and will enable him to use the
different secondary coils of his faradic apparatus to the best
advantage.

18. Condenser.—The addition of a condenser to the
circuit of the primary coil reduces as much as possible the
duration of the variable period when the primary current is
interrupted. No matter what interrupter is employed, at the
moment the primary current is broken, a spark is seen between
the contacts of the interrupter. These sparks are due to the
self-induction of the primary coil and should be avoided for
two reasons—one of which is physical and the other biological.
The spark at rupture is more energetic than would be produced
by the inducing current itself, and its production at each
interruption by self-induction prolongs the duration of the
primary current, because it decreases the resistance of the
air-gap. Instead of an instantaneous interruption there is a
diminution of intensity before the current ceases and the
demagnetization of the soft-iron rods of the core takes place
more slowly, owing to self-induction.

Both of these objections are overcome by placing a condenser
in a derived circuit from one part of the interrupter to the other,
as shown in Fig. 62, *Magnetism and Electromagnetism*. When a
condenser is placed in circuit, the current due to self-induction
discharges into the condenser; the condenser discharges imme-
diately through the primary coil and the battery. This current
of discharge opposes the primary current and demagnetizes
instantly the core of soft-iron rods, and the induced current
of rupture is made shorter and consequently more intense.
Another result due to the condenser that the physician will
appreciate is that the interruptions are made more regular.

From a physiological point of view, also, the condenser is of
importance. The sensation produced by the induced cur-
rent is altogether different, depending on whether the coil is
furnished with a condenser or not. This difference in sensa-
tion is readily observed on testing a given coil with and without

a condenser. The capacity of a condenser suitable for a given coil must be determined by experiment.

19. Secondary Coils.—The secondary of the modern faradic apparatus is now generally composed of either one coil having wires of different length and sectional area and tapped at different lengths, or of two or more coils each of which is composed of a certain length of wire of a specified size. In the Engelmann battery, as modified by Goelet, the secondary is made as follows:

All the different wires are wound on one spool, movable over the primary, and having a rheostat adjusted in the circuit of the primary. First, 238 yards of No. 21 wire is wound on the spool, and divided into two lengths of 84 yards and 154 yards. Next is wound 800 yards of No. 32 wire, which is divided into 300 yards and 500 yards, which, with the total 800 yards, gives three lengths of coil. Over this is wound 1,500 yards of No. 36 wire, divided into 500- and 1,000-yard lengths, giving three divisions of this wire: 1,500 yards, 1,000 yards, and 500 yards. The different lengths of the coil terminate on a hard-rubber head at one end of the spool and the selection is made by means of two movable levers or arms. The E. M. F. in any of these secondary coils depends on (1) the amperage of the primary current, (2) on the resistance of the secondary coil employed, and (3) on the duration of the variable period of opening and closing.

The resistance of the secondary coil employed is governed by the length and sectional area of the wire. It will, therefore, be clear that in order to provide different voltages and different rates of flow it will be necessary to have coils made of different lengths and sizes of wire; hence, the necessity of a set of standard secondary coils. Coils of different lengths and sizes of wire will produce induced currents of different voltages and different rates of flow when placed in magnetic fields of the same intensity that appears and disappears at the same rate. In the physician's induction-apparatus, the magnetic field is produced by the current in the primary coil, and the magnetic field is made to appear and disappear by the interruption in the primary circuit. Each secondary coil that is placed in this field will

produce an induced current whose voltage and amperage are determined by the the number of turns it contains and by the length and cross-section of its wire, and also by the rate at which the magnetic field appears and disappears.

French electrotherapeutists employ three separate secondary coils, made as follows:

1st secondary 1,150 meters of No. 35 wire, R = 1,000
2d   secondary   351 meters of No. 21 wire, R =   15
3d   secondary   96 meters of No. 15 wire, R =   1

The primary coil is made of No. 21 wire and contains 100 meters; the resistance is 4.3 ohms.

Any of these secondaries may be placed over the primary at will. The current-strength is regulated as in all Dubois-Reymond coils, or the secondary may entirely overlap the primary when the current-strength is regulated by a rheostat in the patient's circuit. The rheostat illustrated in Fig. 29 serves this purpose admirably well.

20. Fluid Rheostat by Bergonié.—When a rheostat is included in a patient's circuit for the purpose of adjusting the current-strength through the latter, it is important that the current regulation effected by same should be uniform and free from any sudden variations. This has been the aim in constructing the
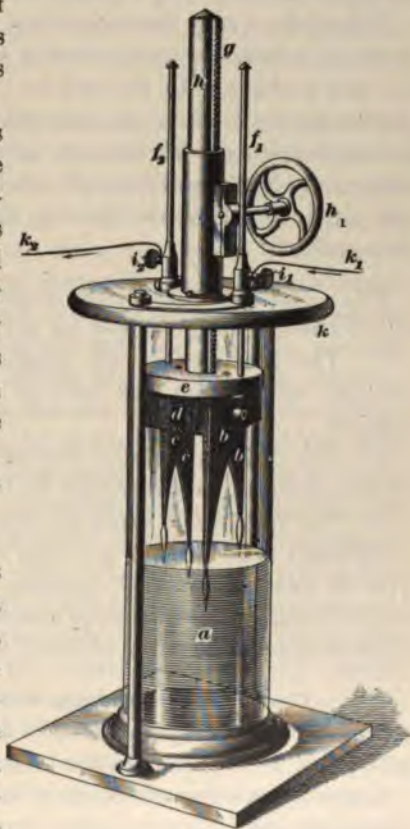
FIG. 29.

rheostat shown in Fig. 29. Into a glass vessel *a* partly filled with water or some other fluid, the glass-tipped carbon tongues *b*, *c* may be made to descend. As the outlines of these are parabolic, the increase in area they offer for the passage of an electric current through them will be in direct proportion to the distance through which they move. They are insulated from each other by means of the ebonite block *d* and attached to a plate *e* through which the rods *f₁*, *f₂* pass in order to connect with them. A plate *k*, also made of insulating material, carries the two binding-posts *i₁*, *i₂*, through which the rods *f₁*, *f₂* may slide.

The plate *e* may be moved up or down by means of the wheel *h₁*, which has on its shaft a small pinion engaging with the rack *g* attached to the rod *h*. When the conductors *k₁*, *k₂* of the patient's circuit are inserted in the binding-posts *i₁*, *i₂*, it is seen that the electric current will descend through the rod *f₁* and carbon *b* into and through the liquid to the other carbon *c* and rod *f₂*, and then out through the other binding-post *i₂* into the conductor *l*.

21. The following factors determine the voltage and amperage of the current produced by any secondary coil:

1. The intensity of the magnetic field produced by the primary current and the rate at which it appears and disappears.

2. The resistance of the secondary coil; this is determined by the length and cross-section of the wire used.

3. The number of turns of wire in the secondary coil.

Different coils do not produce currents of different kinds; they all produce induced currents, but these induced currents vary in voltage and amperage according to the physical conditions existing in both the primary and secondary circuit.

22. Tests for Secondary Coils.—To appreciate the significance of a set of standard coils for the secondary of a faradic apparatus, we recommend the following experiments:

Connect a telephone receiver to the binding-posts of a faradic apparatus and by means of a rheostat in the primary circuit allow the minimum current that will actuate the rapid vibrations to flow through the primary. Now place over the primary

the coil composed of 1,500 yards of No. 36 wire, then the coil composed of 800 yards of No. 32 wire, and finally the coil composed of 250 yards of No. 21 wire. Study closely the sound produced by the current from these different coils, as it will give you a good idea of the current volume produced by each. It will be observed that the volume of sound increases as the length of the wire decreases and as the diameter increases. In other words, the volume of sound produced by the coil of medium size is greater than that produced by the coil of long fine wire and less than that produced by the coil having only 250 yards of No. 21 wire. This is a very practical study and will do much to give the student a clear conception of the function of different coils.

When it is desired to study the comparative values of the E. M. F. of different coils, a rheostat of high resistance is required in series with the coil. When testing the comparative values of the current volume produced by different coils, the maximum current-strength of each coil reached the ear; the E. M. F. of the coils was not changed by any external resistance. With a given resistance in series with the coil it will be observed that the volume of sound increases not from the long to the short coils, but in an inverse direction; that is, from the short to the long coil. From this we conclude that the E.M.F. of the coil of long fine wire is higher than that of the short coarse wire. With a scaled rheostat of high resistance in the secondary circuit the great difference in voltage between the coarse-wire coil and the fine-wire coil is readily appreciated.

The importance of these two experiments in the correct appreciation of the therapeutic value of the currents from coils composed of different lengths and sizes of wire is not easily over-estimated. While studying the current volume of coil-currents by means of the telephone, the maximum current of each coil reaches the ear; it is important therefore that the current in the primary be just sufficient to actuate the vibrator, otherwise the noise would be disagreeably loud if not actually painful. The current-strength in the primary may be considerably increased when testing the E. M. F. of different coils, because part of the current is consumed in the external rheostat.

23. When the secondary coil is composed of wire of three different sizes, Nos. 21, 32, and 36, and tapped by means of two levers at ten or more different places, it is an interesting and instructive study to compare the varying volumes of sound produced by the current from the ten or more different sections of wire of different lengths and sizes of which the secondary coil is composed.

The Congress of Electricians, in 1881, recommended but one secondary coil composed of 5,000 turns of wire in 28 layers. The wire had a diameter of .25 millimeter, the resistance of which was 282.9 ohms. A coil of that kind is far from meeting the therapeutic indications of coil-currents, but it might be useful for its sensory effects in the treatment of certain cases of anesthesia. Such a coil has too much tension and not sufficient quantity. It is self-evident and requires no long explanation that all pathological conditions do not require the same dosage, and it is precisely to provide different dosages of coil-currents, different ratios of voltage to amperage, that the modern faradic apparatus is composed of several secondary coils having wires of different lengths and sizes.

The therapeutic indications of coil-currents may be located in deep-seated organs or nerve-trunks, striated and non-striated muscles. They may also be located in the sensory nerves of the skin, the irritability of which may be increased or decreased; or these currents may be required to influence the vasomotor nerves and nutrition, and in order to meet these therapeutic indications a faradic apparatus with a standard set of secondary coils is indispensable.

PHYSIOLOGICAL EFFECTS OF FARADIC CURRENTS.

24. We shall study the effects of faradic currents on (1) motor nerves and striated and non-striated muscles, (2) sensory nerves, (3) vasomotor nerves, (4) nutrition.

The extra-current of the primary coil, the so-called primary induced current, has the same direction as the battery current, but differs from it in having greater quantity and higher E. M. F. It is therefore a unidirectional induced current and possesses in some degree the properties of the galvanic current. It is both

electrolytic and cataphoric in its effects, but its chief action is as an excitant to contractile tissue by reason of the interruptions, which cause a sudden variation in potential.

The currents from the secondary coils consist of two waves in opposite directions. If these two wàves are isolated by means of a special device and each is allowed to act in a separate circuit, that is, the positive waves in one circuit and the negative waves in another circuit, the currents thus produced can be studied separately. It is found that they have all the properties of rapidly interrupted galvanic currents. These currents can, like the galvanic current, produce electrolytic and cataphoric effects; and by reason of their rapid variations in current-density they cause energetic muscle-contractions. Induced currents differ from direct currents by their duration, which is extremely short; they also differ in that induced currents periodically change their direction.

The difference between the E. M. F. of the two induced currents produced by each oscillation of the vibrator of a faradic coil is sufficiently great that in medical practice the E. M. F. of the inverse current, or current of closing, may be ignored. In fact both currents, the inverse and direct, act mechanically by reason of their E. M. F., but the E. M. F. of the closing, or inverse, current is too feeble to produce any physiological effect whatever. It is only when the electric excitation is very strong, so strong that the direct, or opening, current is no longer supportable, that the inverse, or closing, current is capable of causing muscular contraction. We see then that although the current from the secondary of an induction-coil is an alternating current when acting through low resistances, when applied to the human body it is unidirectional, because the E. M. F. of the inverse current is not sufficient to overcome the resistance of the tissues.

25. Unidirectional, Interrupted, Induced Currents. The currents derived from the secondary of a faradic apparatus are, physiologically considered, **unidirectional, interrupted, induced currents.** It is probable that they possess cataphoric and electrolytic properties however slight; but their chief action

on the human organism is to produce contraction of muscle-fiber, striated and non-striated, and to excite movements in living protoplasm. The currents of the induction-coil are thus seen to be chiefly serviceable in stimulating the activities of the tissues within the range of their physiological action. The currents may also be of low voltage and comparatively high intensity, as for example, the current from the coarse-wire coil, or they may be of very high voltage and feeble intensity, as the current from the long fine-wire coil.

Intermediate coils have voltage and amperages corresponding to the length and cross-section of their wires. They may also be of high or low frequency, according to the rapidity of the oscillations of the vibrator. In order to understand the effect of currents for faradic coils and to intelligently apply these currents, their wave-form or characteristic of excitation should be thoroughly familiar. It will be observed, on comparing Figs. 7 and 13, that there is a marked difference in the configuration of these two wave-forms. The sinusoidal wave, while it periodically changes its direction, is continuous; there is no interruption. The most striking feature of the faradic wave is its interrupted configuration. The faradic wave-form shows a period of inaction or interruption not only between each break and the succeeding make, but also between each make and break; that is, between the appearing and disappearing of the magnetic field there is a period during which it does not vary in intensity.

26. Muscular Contraction.—Faradic currents are very appropriate for the production of muscular contraction, and as muscular contraction is an important factor in the physiological effects and therapeutic results of these currents, a short description of it will be given here. The contraction produced by the faradic current is more energetic when the current is applied to the motor nerve than when it is applied to the muscle. When the motor nerve is stimulated all the nerve-fibers that supply the muscle are stimulated at the same time; the action is more localized when the excitation falls on only a part of the muscle-fibers, as in the indirect application.

Theoretically, muscular contraction is divided into three periods, namely: (1) Latent period, which has a duration varying from .004 to .01 of a second; (2) period of increasing energy, which has a duration varying from .03 to .04 of a second; (3) period of decreasing energy. The period of decreasing energy is generally a little longer than that of increasing energy and has a duration varying from .04 to .06 of a second. If the second excitation takes place during the latent period of the first contraction, there will be only one contraction.

In order to produce muscular contractions of maximum energy the excitations should succeed each other at intervals of $\frac{1}{20}$ second. If the excitations follow each other in rapid succession, the muscle has not sufficient time to relax between the excitations; it maintains a certain degree of shortening and its myographic trace indicates a convulsive trembling. This condition of the muscle is known as tetanus. It is important to recognize that tetanic muscular contraction is not a uniform continuous contraction but a form of discontinuous movements resulting from the superposition of a series of muscular contractions. The production of tetanic contraction requires a certain number of excitations per second, which varies with the length of the individual contractions. When the individual contractions are long, it requires from 8 to 12 excitations per second to produce tetanus; when the contractions are short, from 18 to 20 excitations per second will be required. If the time of tetanic muscular contraction is prolonged, the muscles finally relax, even when the excitations are continued. The relaxation is at first rapid and then slow. This relaxation of muscles is known as the *phenomenon of fatigue.*

The faradic current with each vibration of the interrupter produces a muscular contraction; to produce a tetanic contraction, it requires from 20 to 30 excitations per second. That is the inferior limit. As the number of excitations per second increases, the tetanic contractions also increases; but there is also a superior limit beyond which the tetanic contraction not only does not increase but diminishes and finishes by completely disappearing. This limit has been ascertained by d'Arsonval to be within from 2,500 to 5,000 excitations per second.

27. Polarity of Coil-Current.—As the physiolog effects of faradic currents are due to electric waves having same direction, it is but natural to suppose that it posses polarity. That the faradic current possesses polarity may demonstrated as follows: Place a small electrode on the flex surface of the forearm and complete the circuit by placing large indifferent electrode on the sternal or cervico-dorsa region and gradually increase current-strength until slight contractions are noted in the muscles of the forearm. Without removing the electrodes or altering the current-strength, reverse the current; there will be no contraction of the muscles of the forearm. As only the waves producing a break are considered, the current in the external circuit of the coil flows always in the same direction from one terminal of the coil to the other. The current behaves, then, in the external circuit as a direct-interrupted current; and if the electrode that produced contractions of the muscles of the forearm with a minimum current is traced to the coil-terminal it will be found to be connected to that terminal toward which the current flows. This we know is the negative pole of the faradic current; therefore, this pole produces a more energetic contraction with a given current-strength than the positive. If one electrode is held in each hand and the current increased until moderate contractions are produced in the muscles of the forearm, it will be observed that the contractions are more vigorous in the muscles corresponding to the electrode connected with the coil-terminal toward which the current flows from the external circuit.

If two electrodes of the same area are placed a few inches apart on the flexor surface of the forearm, the sensations beneath the electrode connected to the terminal of the coil from which the current flows in the external circuit are not nearly so strong with a given current-strength as those produced beneath the electrode connected with the terminal toward which the current flows. The terminal from which the current flows is positive and that to which it flows is negative; the negative pole, therefore, produces more energetic contractions and more sensory irritation with a given current-strength than the positive pole. An easy means of determining the polarity of coil-currents

consists in connecting a Geissler tube to the terminals of the coil. The end of the tube in which the violet light appears corresponds to the anode; the other end, or cathode, remains dark.

28. Effects on Striated Muscles.—The researches of Debedat are conclusive regarding the effects of slowly interrupted faradic currents on striated muscle-fiber. Debedat operated on the posterior femoral muscles of the rabbit. He made twenty applications in all, each application consisting of 30 rythmic faradic contractions per minute. The duration of each application was 4 minutes. For every second of muscular action there was 1 second of muscular repose. Debedat assured himself before experimenting that the weight of the posterior femoral muscles of the rabbit was the same on both sides. The weight of the rabbit before the faradic applications were made was 892 grams, and after 20 séances the weight was 1,150 grams, showing a gain of 258 grams.

<div align="center">

TABLE 1.

**DIFFERENCE IN WEIGHT CAUSED BY COIL-CURRENTS
CORRECTLY APPLIED.**

</div>

Weights of the Posterior Femoral Muscles.	Before Electric Applications. Grams.	After 20 Electric Applications. Grams.
Biceps	4.60	6.00
Semitendinosus	1.40	2.10
Semimembranosus	3.50	5.00

This shows the increase in weight due to the electric applications. By palpation it was also easy to detect the increase in volume of the muscle that had been rythmically faradized. Histological examination demonstrated that the hypertrophied muscles had all the appearance of normal muscles. The muscle-fibers were regular, the striation was distinct, and the interstitial tissue was scarcely apparent. The faradic application as applied by Debedat produced hypertrophy of the muscular-tissue itself.

29. To demonstrate the effects of coil-currents incorrectly applied, Debedat employed the same current that he caused to act rythmically and within the limits of physiological exercise in his first experiment, but he increased the number of vibrations per minute so that tetanic contraction was produced. After 20 séances of 4 minutes' duration, the results were as follows:

TABLE 2.

DIFFERENCE IN WEIGHT CAUSED BY COIL-CURRENTS INCORRECTLY APPLIED.

	Before Electric Applications. Grams.	After 20 Electric Applications. Grams.
Weight of rabbit	682.00	720 00
Weight of posterior femoral biceps . .	3 20	3.05
Weight of posterior femoral semitendinosus	1.20	1.20
Weight of posterior femoral semimembranosus	2.40	2.25

Here there was true atrophy of the muscular substance itself. In the muscles that were atrophied, lesions were easily observed in the muscle-fiber itself without any apparent reaction in the interstitial tissues.   The results of these physiological experiments of Debedat prove conclusively that the therapeutic effects of faradic currents may be beneficial or otherwise, according to the technique of applying them.   If in a case of traumatic muscular paralysis the faradic current is applied so as to produce tetanic contractions for 3 or 4 minutes, the conditions of the muscles will not be improved, but on the contrary it will be made worse.   To apply the faradic even in a case as simple as this, requires a thorough understanding of the laws of electrobiology.

30. Effects of Fine and Coarse Coils.—The different effects of the long fine coil and the short coarse coil, both operating through low resistance, may be well observed in making a vaginal application in a healthy woman.   Place

in the vagina the bipolar vaginal electrode connected with the long fine coil; its action will be agreeable and sedative. Now disconnect the electrode, and join it to the short, coarse coil; the effect will be altogether different. The sharp, strong contraction produced will be painful. Now, with the same coil-currents make a percutaneous application. The effects produced percutaneously, like those produced permucous, will be found to vary with the alterations in the electromotive force, with the changes in current-strength, and the varying resistance of the tissues. It will be readily understood that a current of high voltage will penetrate more deeply than a current of low voltage, the resistance remaining the same. If a current penetrates more deeply, it is more diffused; its action is spent on a larger tissue area; it must necessarily be milder and more sedative than if it were limited to a smaller area. The coarse-coil current lacks penetrating power on account of its lower voltage. It is limited to a small area of tissues, and hence its stimulating quality. The long fine coil, by virtue of its high voltage, penetrates deeply, diffuses into tissues, affects a large area, and is sedative in its quality. The current from any coil will vary with alterations in the inducing force, in the rapidity of interruptions, and with the resistance in circuit.

31. Effects Produced by Slow and Rapid Interruptions.—A slowly interrupted faradic current produces isolated muscular contraction, with increase in nutrition and increase in physiological development. A rapidly interrupted coil-current tetanizes muscles, and produces muscular anemia and histological degeneration. Interruptions varying from 200 to 3,000 periods per minute cause electric massage, and are much used in pelvic inflammatory troubles when pain is not a symptom. They do not produce sedative effects, and are not adapted to stimulate groups of muscles when the object is to improve nutrition. The utility of coil-currents in the treatment of diseased conditions is not limited to their power of contracting muscles. Indeed, they often appear more effective than the direct current when judiciously used in neuromuscular maladies attended with reaction of degeneration.

Slowly interrupted coil-currents have very little action on non-striated muscles, but when rapidly interrupted, the non-striated muscle-fiber responds vigorously. Each fiber contracting successively, the normal vermicular movement of the arteries and arterioles is stimulated. This accelerates the flow of blood and lymph through the tissues, relieves venous stasis and areas of congestion, promotes absorption, and increases the elimination of waste material.

32. Use of Coarse-Wire Coil.—As a muscle-stimulator, the current from the coarse-wire coil is to be preferred. When using the coarse-wire coil, on account of its low voltage, the resistance of the tissues should be lessened by using large electrodes and thoroughly saturating the skin. In uterine subinvolution, the infiltration between the bundles of muscle-fibers decreases uterine muscular contractility. In these cases the current from the coarse-wire coil, on account of its greater amperage, and therefore greater stimulating property, is particularly indicated. The low resistance of pelvic tissues is suited to the low voltage of the coarse-wire coil, and the greater amperage or stimulating property of the coarse-wire coil adapts itself well to the decreased uteromuscular contractility.

33. Use of Fine-Wire Coil.—In large, soft myomas, Doctor Massey speaks well of the action of the primary current in producing muscular contraction. The rapidly interrupted current from the large fine-wire coil may also be used to contract muscles, but its chief use is to establish local unconsciousness, to allay pain, and to procure sedation. How the rapidly interrupted current from the fine-wire coil allays pain and procures sedation is not yet satisfactorily determined. Doctor Goelet claims that it is due to a temporary paralysis of the motor and sensory nerves acted on by the current. The relief of pain that follows the application of these currents, in the manner described for producing sedation, may be explained in this way, viz., the rapid succession of impulses imparted by the interruptions may be regarded in the nature of a percussion that induces a condition of concussion of the nerve-filaments, impairing their condition to conduct painful impressions. The intense

stimulation of the motor nerves produces a tetanic contraction of the muscles that eventually wears out their contractility, producing relaxation, or a temporary local paralysis that means rest for the diseased parts they encompass. It is probable, also, that relief of the congestion on which the pain may, in a great measure, depend, is another way in which this result is reached.

34. Sedative Properties of Rapidly Interrupted Current.—Both muscles and nerves, by the tetanizing action of the current, have their irritability rapidly exhausted. Apostoli attributes the sedative effects to the direction in which the electric impulses travel. He supposes that they are in a direction against the impulses of pain, and in that way annul their effect. Dr. W. J. Morton explains the sedative properties of the rapidly interrupted current, by assuming that the nerve-filaments of the area acted on by the current are in a condition resembling that of cerebral concussion. The current acts mechanically by producing a commotion like that caused by a blow or an injury to the cerebrum. A strong faradic current from the long fine coil, rapidly interrupted, tetanizes the muscles, both striated and non-striated, exhausts rapidly neuromuscular irritability, and destroys pain. As a sedative benumbing agent, this current is much employed in gynecology. Its pain-relieving properties in pelvic maladies are second only to opium. Its properties to stimulate muscles are used in various diseases of the neuromuscular system.

35. Fatiguing Quality of Current.—The fatiguing quality of the current is employed in the treatment of spasmodic contractions and in hysterical contractions. The current is applied to the contracted muscle until it is thoroughly relaxed. Contraction takes place again shortly after the treatment, and the applications must be continued daily until a cure is effected. The current will give good results in this way in many orthopedic cases. In using coil-currents from either the coarse-wire coil or the fine-wire coil, whether with fast or slow interruptions, fix clearly what it is desired to accomplish, and with this end in view apply the current. The effects of high-tension induction-currents on body nutrition have been very clearly investigated

within recent years.   M. d'Arsonval's experiments show that general faradization increases respiratory functions by stimulating the muscular system and also the sensory nervous system. General faradization, therefore, increases nutritive changes either with or without muscular contraction.

36.   Retardation of Nutrition.—Analysis of urine made by Doctor Berlioz proves the efficacy of high-tension induction-currents in all those diseases characterized by retardation in the processes of nutrition.   The increased activity in oxidation was shown in the diminished amount of uric acid and the increased amount of urea eliminated.   Mineral products and organic waste are also better eliminated.   These currents increase the appetite and improve digestion.   Return to natural sleep with a renewed power for work, both mental and physical, are among the effects first noticed.   The diseases most amenable to treatment by these currents are gout, rheumatism, and diabetes.

37.   Action on Muscles.—When both electrodes are applied directly to the skin, the action of rapidly interrupted currents depends on the electromotive force.   With moderate E. M. F. the reaction is principally on the skin, which becomes reddened, due to the stimulation of the vasomotor nerves. There is also a pricking sensation, due to irritation of the sensory nerves.   With increasing E. M. F. the muscles beneath the skin are thrown into tetanic contraction, which, if persisted in, will quickly produce fatigue and exhaustion.   The neuro-muscular response will be quicker and more energetic if the electrode is placed over a motor point.   Changing the position of the electrode rapidly from one motor point to another, or touching the same motor point at as short intervals as possible, causes an agreeable tonic exercise of the muscles, which restores lost tone and gives renewed energy to fatigued muscles.   This action of the tetanizing current on muscles is very important and deserves special attention.   A large part of the therapeutic action of coil-currents in human tissue depends on their power to contract muscle-fiber, and on the rapidity and varying durations of these contractions will depend the different effects produced.

38. Vasomotor Effects of Currents.—If a tetanizing contraction is long maintained, fatigue and exhaustion must follow. But when the tetanizing action is only momentary, as when the electrode is rapidly shifted from one motor point to another, the blood- and lymph-currents within the muscles are accelerated, the muscles receive an increased supply of oxygen, and thus energy and vitality are quickly restored. The lightness and buoyancy experienced in the muscles thus exercised are due to the vasomotor effects of the current in increasing the supply of oxygen to the muscles, giving new life and energy.

39. Vermicular Action.—Rapidly interrupted induction-currents produce a vibratory movement in the protoplasm of the body, and, as protoplasm constitutes nine-tenths of the body, and nine-tenths of its most vital parts, the influence of these currents may be better appreciated. The vermicular motion of the blood-vessels and intestines is increased in the direction of the current. Polarity must therefore be considered when the effects of these vermicular movements are required. The vasomotor nerves and the visceromotor nerves are very actively stimulated by rapidly interrupted currents. Stimulation of the visceromotor nerves increases the peristaltic action of the intestines, accelerates the blood-current in the intestines, promotes intestinal secretions, and relieves constipation. They increase the secretions of serous surfaces, for by them a dry and creaking joint may be made to secrete. Glandular secretion in general is stimulated, and the entire sympathetic system comes within its range of action. The physiological action of these currents on the vasomotor, visceromotor, and secretory nerves explains its therapeutic use in a wide range of diseases.

40. Pelvic Effects of Currents.—The pelvic effects of currents both from the coarse and the fine coil require special attention. The mucous tissues of the pelvis conduct electric currents with the same facility as saline solutions. This good medium of conductivity is surrounded by a bony wall a poor conductor; hence it is that the electric current permeates all of the pelvic viscera. The bipolar method of treatment, dispensing with the inconvenience and pain of the unipolar method, has

done much to popularize the use of electricity in pelvic diseases. The bipolar method permits also the use of much stronger currents than were heretofore used, and concentrates them on the organs to be treated. Resistance is still further diminished by placing both poles near each other on the same electrode.

41. Uterine Treatment.—The vagina and uterus are comparatively insensitive to electric currents, and much stronger currents can be used, since the painful cutaneous surface is eliminated, and the resistance is less than that of the skin. The electric current must not be turned on until the electrode is well placed within the uterus or within the vagina; it must be supported by the hand during the séance, and must not be removed until the current is turned off. Special care should be taken to see that the external pole of the electrode does not come in contact with delicate, sensitive structures at the vulvo-vaginal junction. The poles of the bipolar vaginal electrode are 1½ inches apart, and those of the uterine electrode are 1 inch apart. The internal os is very sensitive to the electric current; both poles of the uterine electrode should therefore be well within the body of the uterus before the current is turned on, and should be maintained there by the hand during the entire séance and until the current is turned off. By observing these few details the patient may be spared much pain.

42. The current from the coarse-wire coil is used to stimulate and contract the muscles in the pelvis. This current was particularly studied and developed by Tripier, as the fine-coil current was by Apostoli. Flexions are corrected and the development of the uterus increased. Passive congestion and subinvolution are removed by the stimulating and contracting powers of coarse-wire currents. A large relaxed discharging uterus, under the use of this current, soon regains tone and diminishes in size, while the endometrium returns to its normal condition. In using the coarse-wire coil for these purposes, slow interruptions alone are used. Relaxed pelvic tissues from any cause, and relaxed vaginal walls, are amenable to treatment by this current. The chief pelvic effect of the fine-wire

coil-current is to relieve pain and congestion. The pelvic effects of the current from the fine-wire coil depend on the method of administration, strength of current, and the rate and quality of interruptions. When stimulation is desired, short applications are the rule. When sedation is required, the séance should last from 15 to 30 minutes, and the current must be turned on gradually and evenly. There is not much danger of producing too much sedation.

43. Massage Effects.—To produce massage effects, interruptions varying from 1,000 to 2,000 per minute are used, and the séance must be short. To procure sedation, the maximum rapidity attainable is used, and the séance should be long. The current from the long fine-wire coil may be made stimulating by increasing its strength rapidly and maintaining the strength at a point where it is felt throughout the entire séance. For this purpose the application should not be prolonged beyond 5 or 10 minutes. A sedative application may be converted into one that is stimulating by changing the number of vibrations per minute. Extremely rapid vibrations are sedative; coarse vibrations from the long fine-wire coil are stimulating.

44. Summary.—When the indication for treatment is principally to act on the circulation, the unipolar method should be used, because the circulation is increased when it has the same direction as the current, and vice versa. Acute inflammatory conditions of the ovaries, tubes, or periuterine tissues are much benefited by the current employed in this manner. The pain is allayed, congestion relieved, and the exudations and infiltrations are absorbed. They impart a tonic condition to all pelvic viscera. The principal facts to remember in applying coil-currents to the treatment of pelvic maladies are:

1. The primary current may be used to produce muscle-contraction.

2. The coarse secondary coil is irritating and muscle-contracting, and with interruptions varying from 1,000 to 2,000 per minute, massage effects are produced. The séance should be of short duration.

3. The long fine-wire coil may be used to contract muscles, the contractility of which is not impaired, but its chief use is to allay pain and produce sedation. When used to produce sedation, the séance should last from 15 to 30 minutes.

4. By making the interruptions coarse, the current from the long fine-wire coil becomes irritating.

5. By increasing the current-strength rapidly, and maintaining it at a point where it is perceptible during the whole séance, the fine-wire coil-current is rendered irritating; and is indicated to produce absorption of inflammatory material and effete products where the pelvic tissues are not sensitive.

PERIODIC INDUCED CURRENTS.

45. Periodic Induced Currents in Gynecology. Under this name Dr. A. H. Goelet has grouped the following three currents, each of which is derived from an apparatus of special construction: (1) The interrupted induced current, derived from the long fine-wire coil of the scientifically constructed coil-battery; (2) the sinusoidal current, derived from the sinusoidal machine; (3) the static induced current derived from the static machine with Leyden jars in circuit.

The static induced current, on account of the bulk and weight of the static machine, is restricted entirely to office-practice. The sinusoidal machine is non-portable, somewhat costly, and requires the street current for its operation. The scientifically constructed coil-battery provided with dry cells is portable, comparatively cheap, and the current from its long fine-wire coil fulfils perfectly all the therapeutic uses of the currents from the other two machines.

46. Stimulating Property of Periodic Induced Currents.—The most noticeable effect of periodic induced currents is a muscle, nerve, and circulatory stimulation, the latter depending mainly on the action of the vasomotor supply. The degree and nature of this stimulation depend on the E. M. F. and amperage of the current employed and the rapidity of the impulses imparted by the interruptions. In the coil-battery, the stimulating property of the current is governed by the

length and size of the wire composing the secondary coil, which regulates the E. M. F. and amperage of the secondary current, the force of the primary current being constant, or very nearly so. The rapidity of the interruptions is controlled by the automatic vibrator in the primary circuit. The advantage, then, of a number of secondary coils, having different lengths of the same wire and different sizes of wire, is that the stimulating property of the current may be conveniently and gradually increased and decreased.

47. Stimulating Property of the Sinusoidal Current.—In most of the sinusoidal machines, now in the market, the primary magnetic field is produced by permanent magnets, and the secondary current is received from coils rotating in this field. The E. M. F. and rapidity of alternations are increased by increasing the speed of the machine—that is, by increasing the number of the revolutions of the armature or revolving disk. The volume of the current will depend on the resistance in the patient's circuit, and may be varied by means of an adjustable resistance.

48. Stimulating Property of the Static Induced Current.—In the case of the static induced current, the stimulating property of the current depends on the size of the Leyden jars and the distance between the discharging-rods; that is, the size of the jars represents the volume of the discharge, and the air-gap between the discharging-rods regulates the rapidity of the impulses. The amperage and rapidity of interruptions of the current are regulated in the same manner as the currents from the coil-battery, the small-, medium-, and large-sized jars taking the place of the fine-, medium-, and coarse-wire coils of the battery.

49. Comparison of Currents From Coarse and Fine Coils.—The marked difference in the effect produced by currents derived from the long fine-wire and the short coarse-wire secondary is just what would be anticipated from their different natures and properties, the latter being a current of low E. M. F. and greater volume, and the former possessing a high E. M. F. but an almost inappreciable volume.

As shown by Duchenne, the current from the short coarse-wire coil acts more directly on the muscles (lacks penetrating power), increasing their contractility, and is more localized; and the current from the long fine-wire coil acts more especially on the sensory nerves and penetrates more deeply. It may further be said that the current from the long fine-wire coil diminishes muscular contractility; for, though the first effect may be that of a stimulant, it is secondarily sedative. The immediate effect of both forms of this current is therefore a stimulation; but the one, the current of volume, produces muscular stimulation, and the other, the current of tension or high E. M. F., produces a nerve stimulation; and in employing periodic induced currents, these facts must be borne in mind.

EFFECTS PRODUCED BY COIL-CURRENTS.

50. One of the most important effects produced by these currents is an increase in tissue-metabolism, increased absorption of oxygen, and a corresponding increased elimination of carbon dioxid by the tissues and coincidently increased nutrition. They therefore accelerate the functional activity of organs brought under their influence. This effect of the current can be readily demonstrated. Its power to increase perspiration may be shown by grasping in one hand the bipolar vaginal electrode, and using the fine-wire current as strong as it can be borne for a few moments. The hand becomes bathed in perspiration. At the same time, another very important phenomenon will be observed; namely, the hand, but more particularly the fingers, soon become pale and bloodless. This pale bloodless condition of the hand and fingers is due to the tetanic contraction of the muscles and to the effect of the current on the vasomotor supply. This one simple experiment very strikingly illustrates the action of faradic currents on the vasomotor nerves, which influence is of the first importance in the electrical applications for pelvic diseases. Improvement in the general health out of all proportion to that of the local condition has often been noted, even when only local applications have been made to the female pelvic organs.

51. Capillary Circulation Stimulated by Faradic Currents.—The power of faradic currents to promote rapid absorption of inflammatory exudates may be attributed directly to stimulation of the capillary and lymphatic circulation. Faradic currents stimulate the capillary circulation:

1. By exciting an increased vermicular contraction of the smaller arteries, the blood-pressure is augmented. This causes momentary distension of the capillary vessels, the reaction from which, owing to their elasticity, empties or unloads them into the veins. In case of any obstruction in the capillary vessels, this distension, together with the increased blood-pressure, favors its removal.

2. By stimulating the contraction of adjacent muscles, the veins are emptied, and a void is created in their intervalvular spaces, which invites the blood from the overloaded capillaries.

52. Lymphatic Circulation Stimulated by Faradic Currents.—Faradic currents stimulate the lymphatic circulation in two ways:

1. By stimulating the processes of absorption.

2. By stimulating the contraction of adjacent muscular structure, with the effect that the circulation in the lymphatic vessels is increased. These vessels being supplied with valves similar to those found in veins, the contraction of surrounding muscles empties the intervalvular spaces, and invites the flow of lymph from the lymph-spaces when absorption takes place. As the result of this action on the capillary circulation and lymphatics, pelvic congestion is relieved and rapid absorption of infiltrations and exudations is accomplished. The faradic current is unquestionably the most powerful, the most certain, and therefore the most valuable vasomotor constrictor that we possess.

53. Sedative Effects of Faradic Currents.—Perhaps the most important effect of faradic currents of high E. M. F. and great frequency is the production of sedation and the relief of pain. As pointed out by Duchenne, the special action of these currents is on the sensory nerves, and it partakes of the nature of an excitation; but this excitation or stimulation

will result in sedation if certain conditions are observed. This appears to involve an inconsistency, but it will be remembered that while opium is a cerebral and circulatory stimulant, yet its effect is sedative.

54. Rate of Interruptions Governed by Desired Effects.—The rapidity of interruptions has likewise an important bearing on the result, since the more rapid they are, the more soothing the result. Therefore, for a sedative effect they should be as rapid and as smooth as possible. In using the coarse-wire current for muscle-stimulation, the interruptions should be slow, so as to allow an alternate contraction and relaxation similar to the normal physiological action of the muscle.

55. Frequency of Applications.—The frequency of the applications and the subsequent behavior of the patient are also to be considered. Three times a week may be sufficient when stimulation is required, and the patient may not be restricted in her movements especially to attain this result. But sedative applications should be made every day, and in some instances several times a day; but, to be productive of the best results, they should be made after the patient has retired for the night, or she should be made to recline for at least an hour or two afterwards. This is not always essential, however, for in very many instances the relief obtained continues for hours, even when the application is made in the physician's office and the patient is permitted to exercise moderately afterwards.

THERAPEUTIC USE OF COIL-CURRENTS IN FEMALE PELVIC DISEASES.

56. As a therapeutic measure for the relief of pelvic pain and congestion, pelvic inflammations and their results, and infiltrations and exudations, this form of electricity is incomparable with any other agent that we possess. It is to be regarded not only as a remedy against the symptoms accompanying diseases of the female pelvic organs, but often as a curative agent as well, though frequently it serves only as an auxiliary

to the other remedies. In cases where the disease is so far advanced that a cure cannot be effected, and some radical operation is necessary, it serves an exceedingly useful purpose in placing the patient in the best possible condition to withstand it, and aids its success by improving greatly the local condition and her general nutrition.

57. The coarse-wire current is particularly serviceable when there is loss of muscular tone and venous engorgement, such as in subinvolution; but it is absolutely contraindicated in sensitive and inflamed conditions.

DETERMINING THE LENGTH AND SECTIONAL AREA OF WIRE USED IN ANY COIL.

58. Connect the coil to be tested with the binding-posts of a galvanic battery, and turn on the current until the milliammeter registers 5 or 10 milliamperes. Now switch off the coil, and in the circuit place coils of German-silver wire of known resistance, until the needle comes back to the position it occupied with the coil to be tested in the circuit. This will then be the resistance of the coil. These resistance-coils are furnished with a cabinet apparatus. Knowing the resistance of the coil, the length and the sectional area are quickly determined by consulting the table of resistances of different sizes of copper wire, according to Brown & Sharpe's American gage. A coil of No. 36 wire that has a resistance of 200 ohms contains 480 feet, or 160 yards. The result is obtained by multiplying the number of ohms resistance by the number of feet per ohm of the wire, according to the table.

TABLE 3.

TABLE OF RESISTANCES OF DIFFERENT SIZES OF COPPER WIRE, ACCORDING TO BROWN & SHARPE'S AMERICAN GAGE.

Gage Number.	Weight. Feet Per Pound. (Silk-Covered.)	Ohms of Resistance Per 1,000 Feet.	Feet Per Ohm.
14	75	2.504	400.0
15	95	3.172	316.0
16	120	4.001	250.0
17	150	5.040	198.0
18	190	6.360	157.0
19	240	8.250	121.0
20	305	10.120	99.0
21	390	12.760	76.5
22	490	16.250	61.8
23	615	20.300	48.9
24	775	25.600	39.0
25	990	32.200	31.0
26	1,265	40.700	24.6
27	1,570	51.300	19.5
28	1,970	64.800	15.4
29	2,480	81.600	12.2
30	3,050	103.000	9.8
31	3,920	130.000	7.7
32	4,930	164.000	6.1
33	6,200	206.000	4.9
34	7,830	260.000	3.8
35	9,830	328.000	2.9
36	12,420	414.000	2.4

INTERRUPTIONS OF INDUCED CURRENT.

59. The rate and character of the interruptions of the induced current have so much to do with its therapeutic properties that some ready way of testing them is very important. If the bipolar vaginal electrode is held in the hand, and the current turned on from different coils and at different rates of interruption, with different electromotive forces and different resistances, any jerk or uneven action can be detected, and the effect of alterations in E. M. F. and resistance may be studied.

The telephone forms a ready test, and through it the quality of
the interruptions is closely studied. Any length of coil may be
connected with the telephone, and, with the receiver placed to
the ear, the quality of the interruptions with slow and rapid
vibration, with coils of wire of different lengths and sizes, may
be studied and regulated at will.

SECONDARY-CURRENT CONTROLLER.

60. The advantage of a secondary-current controller is in
regulating the application. By its means the current can be
gradually applied from the slightest sensation beneath the
electrode to the toleration of the patient. A secondary coil has
not acquired its full therapeutic properties until it is submitted
to the entire inductive influence of the primary coil. To do
this, it must completely overlap the primary coil. It is always
better to have the secondary coil fixed over the primary, and
then regulate the current through the secondary-current con-
troller. Any change in the relative positions of the primary
and secondary coils, which always influences the current-strength
in the primary coil either by increasing it or decreasing it, must
necessarily interfere with the oscillations of the vibrator, inter-
rupting for the time its smooth and even action. In those
faradic applications, the chief object of which is to secure
sedation, all sudden changes in the vibrator are irritating, and
will render the production of sedation impossible.

The chief factors in providing a smooth and even action of
the vibrator are: (1) A condenser in a derived circuit of the
primary; (2) secondary coil stationary during the entire séance
and current regulated by means of rheostat in patient's circuit;
(3) the vibrator spring and the platinum tip should be thor-
oughly brightened; (4) the vibrator should be properly
adjusted to the degree of E. M. F. in the primary.

VASOMOTOR AND SENSORY EFFECTS OF FARADIC CURRENTS.

61. The vasomotor and sensory effects of faradic currents depend on: (1) The coil employed, whether coarse, medium, or fine; (2) the number of interruptions; (3) the duration of the application; (4) current-density; (5) resistance of electrodes; (6) whether or not the coil is provided with a condenser. The sensory effects produced by faradic currents are more widely known than those of other currents, because almost every one has at some time or another held the rheophores of a faradic apparatus in his hand. The sensory effects result from a series of elementary impressions, the total of which constitute the general sensation experienced in the tissues beneath the electrode.

62. Termination of Nerve-Fibers.—The sensory nerve-fibers of the skin terminate into two ways: The terminal fibrils of the axis-cylinder pass in between the epithelial cells of the epidermis and are known as the interepithelial arborizations. These are the only nerve terminations that are found in the epidermis. They are important in the study of electric sensibility because they represent the first nerve-tissue encountered by the electric current in its passage through the body. The second form of terminations consists of corpuscles and are known as the tactile corpuscles of Meissner and the corpuscles of Pacini. The tactile corpuscles of Meissner are located in the papillæ of the skin of the fingers and toes. The Pacinian corpuscles are situated on some of the cerebrospinal and sympathetic nerves, and especially on the cutaneous nerves of the hands and feet and in branches of the large sympathetic plexus of the abdominal aorta. They occur also on nerves of the mesentery and on articular nerves. The interepithelial arborizations are situated in the epidermis, the tactile corpuscles of Meissner in the true skin, and the Pacinian corpuscles beneath the skin.

Physiology teaches that each of these terminations has a special function. The physiological import of the Pacinian

corpuscles is not yet definitely determined. On account of
their anatomic distribution, it is thought that they receive
sensations of pressure. The tactile corpuscles of Meissner, as
their name implies, have for their special function the sensation
of touch. In the case of the electric current, whether applied to
the skin as galvanic, static, or faradic current, it is important
to know which of these sensory terminations is especially
affected. The interepithelial arborizations are present in the
epidermis on all parts of the surface of the body, and also
between the epithelial cells on the mucous surfaces of the
canals and cavities of the body. They are, therefore, not
only the first nerve-structures affected by the electric cur-
rent but they are also impressed by a greater current-density
in the same application than either the corpuscles of
Meissner or Pacini on account of their closer proximity to
the electrode.

63. Cause of Electric Sensibility.—If the tactile cor-
puscles of Meissner and the corpuscles of Pacini alone were
affected by electric excitation, there would be places in which
very little or no sensation would be experienced during the pas-
sage of an electric current, as there are parts of the body where
these corpuscles are absent or very few in number. As the
electric current produces its peculiar sensation as well on one
part of the body as on another, it is likely that this electric sen-
sibility is due to excitation of the interepithelial arborizations.
When, however, the current reaches a certain value and the
electric excitation is strong, all the sensory nerve terminals are
affected; this explains why the electric sensibility varies in
different regions of the surface of the body. With a feeble
current, therefore, such as is used in producing minimal sensa-
tions, the interepithelial arborizations are alone affected; but
when a strong current is employed, all sensory terminations
are influenced by the passage of the current.

The electric current, in whatever form it may be employed,
can only affect the deeper organs of the body after having first
acted on the skin or the mucous membrane and their nerve
terminals. The intensity of an electric current applied to the

body is governed by the sensation, more or less painful, it produces in the tissues beneath the electrodes. The therapeutic effects of electric currents depend, in a large measure, on the quantity of electric energy that is caused to act within diseased tissues or organs. If the sensibility of the skin is but little affected, high-current intensities may be employed; if, on the contrary, the various conditions that render the current non-painful are neglected or improperly applied, only feeble currents can be employed. The electric sensibility of the skin and the conditions that increase or decrease it are of practical importance and should be familiar to every physician using electric currents.

64. Variations in the Effect of the Secondary Current on Nerves and Muscles.—The physician's induction-coil is capable of giving a great many variations in the quantity and strength of its secondary current. In many cases the effects produced may be entirely the opposite from the ones intended, and it is therefore important to know how the various variable elements contribute to change the qualities of the current.

In the first place it should be remembered that the energy expended in the primary coil of the faradic apparatus depends on two factors—voltage and amperage. The product of these factors gives the watts expended in the primary coil. The energy delivered by the secondary coil depends on the energy with which the primary coil has been provided, and will always be less. For instance, if the current through the primary coil has a strength of .4 ampere, or 400 milliamperes, and is sent through at a loss of 1.6 volts, the energy consumed will be $W = C \times E = .4 \times 1.6 = .64$ watt. Let the primary coil consist of 1,100 turns and be surrounded by a secondary coil containing 11,000 turns of finer wire. The voltage that will be produced in the coil should, theoretically speaking, be 10 times greater than that utilized by the primary, or $10 \times 1.6 = 16$ volts, but would in reality be somewhat smaller.

The energy delivered by the secondary coil when on short-circuit cannot be greater than that given to the primary and

cannot, therefore, be more than .64 watt. If the voltage is equal to 16 volts, then the amperage must be $C = \dfrac{W}{E} = \dfrac{.64}{16}$ $= .04$ ampere, or 40 milliamperes; that is, one-tenth of that in the primary coil. We see, then, that the amperage in the secondary coil is decreasing at the same ratio in which the pressure is increasing. The current-strength will, in reality, be somewhat smaller than this, depending on the efficiency of the coil. Some losses are bound to take place, partly by reason of losses from heating the coils and core, and partly because the secondary coil is unable to use the whole magnetic field produced by the primary coil.

We may still further increase the number of turns in the secondary coil until they, for instance, amount to 100 times that of the primary. The voltage should then be 100 times that of the primary, but the amperage will have suffered a further reduction to $\dfrac{400}{100} = 4$ milliamperes. It will therefore be clear that by increasing the number of turns in the secondary coil no increase in available energy can be obtained; but that, on the contrary, whatever gain is made in pressure or voltage is followed by a corresponding loss in amperage.

65. Cause of Reduction in Amperage.—It must not be thought that this reduction in amperage is caused only by the increased resistance of the secondary coil, owing to the increase in the number of turns and the decrease in the wire diameter. While these do in all cases have some effect, the main cause must be looked for in the self-induction of the secondary coil, which acts as a counter E. M. F. and reduces the induced E. M. F. The reduced current-strength in a secondary coil does not, therefore, result from any actual increase in resistance, but rather from an apparent increase in resistance caused by the reduction in pressure that will occur as soon as a current begins to flow through the secondary coil. This self-induction increases with an increased number of turns and with a lowering of the external resistance, because in the latter case a stronger current tends to flow through the coil.

Engelmann has made extensive investigations regarding the current flow through the secondary of a faradic coil as influenced by various factors. He found, for instance, that when a fine-wire coil of 1,030 ohms' resistance was sending a current through a body of 3,000 ohms' resistance, the available current-strength was reduced to 22 per cent. of what it should have been. In a coil of heavier wire, under the same conditions, the current-strength was reduced only to 78 per cent. of its full value. This experiment of Engelmann is very important, as it enables the physician to understand the cause of the difference of effects observed in current-applications from the long fine-wire coil according as the application is percutaneous or permucous; that is, through a high or through a low resistance.

To some students, it may seem difficult to understand why the various secondary coils that constitute parts of a faradic apparatus and that individually may have E. M. F.'s induced in them varying between 25 and 300 volts should not be able to produce very much heavier currents than they do. In particular does this seem strange when they are connected with low external resistances. It would seem that in the same manner as a heavier current is furnished by a voltaic battery, when its E. M. F. is increased by increasing the number of its elements, a secondary coil would likewise be able to provide a heavier current when its number of turns and thereby also its E. M. F. is increased. But so far from this being the case, the opposite holds true and a decrease in current-strength is the result. Why this is so has already been explained, and in addition it may be said that it could not well be otherwise. If an increase of E. M. F. in a secondary coil would also be followed by an increase in amperage, it would be possible to multiply the available energy almost infinitely and one would, in fact, be creating energy out of nothing.

66. It should not be understood from the preceding that a coil of many turns of fine wire and able to furnish a high E. M. F. always will deliver a current of smaller strength than that furnished by a coil of fewer turns of coarse wire. What

the current-strength will be in either case will depend on the conditions in the external circuit. In some cases, when the body resistance is of a certain value, both coils may deliver currents of the same strength, and the muscular and sensory effects may be equal with both.

We may, for instance, understand how, by reducing the external resistance through which a fine-wire coil is acting, the current that it furnishes may increase in strength but at the same time decrease in pressure by reason of the counter E. M. F. produced in the coil. On the other hand, a coarse-wire coil that normally delivers a relatively heavy current may have the latter reduced in strength by being compelled to send it through a greater external resistance. While in this manner the current from the fine-wire coil is increasing and that from the coarse-wire coil decreasing in strength, we may suppose that at a certain value of the external resistance the amperage through both coils may be the same. Engelmann found that with a certain faradic coil this equality was established when the resistance through the body was 300 ohms and the contact surfaces were made of minimum resistance by using moist electrodes. When the latter were replaced by metallic electrodes applied to the dry skin, this resistance would have to be reduced to 200 to 300 ohms before the coarse-wire coil could equal the fine-wire coil in current-strength. While attempting to look for the reason for this we must remember that the coarse-wire coil is one of low E. M. F. and that therefore at high resistance it will be powerless to send any current through the circuit. Its proper place is, therefore, in connection with circuits of relatively low resistances. In circuits of higher resistance it is working at a disadvantage and its amperage will decrease as resistance is added. Its qualities are somewhat similar to those of a voltaic battery in which the elements are connected in parallel. At low resistances such a battery is able to deliver a current of high amperage, but at the low pressure of 1 cell. When its elements are connected in series, its pressure is greatly increased, but its maximum current-strength is simply that of one element on short-circuit. To work at its best it must, in the latter case, be connected with circuits of high resistance

where only currents of small strengths are required, as otherwise too much energy will be lost in the battery itself.

67. To further elucidate this point, let us take a faradic coil having its secondary coil made up of three separate coils, such as is diagrammatically shown in Fig. 30. The coarse coil *d* is one of 1 ohm resistance and 25 volts; a finer one *e* of 15 ohms
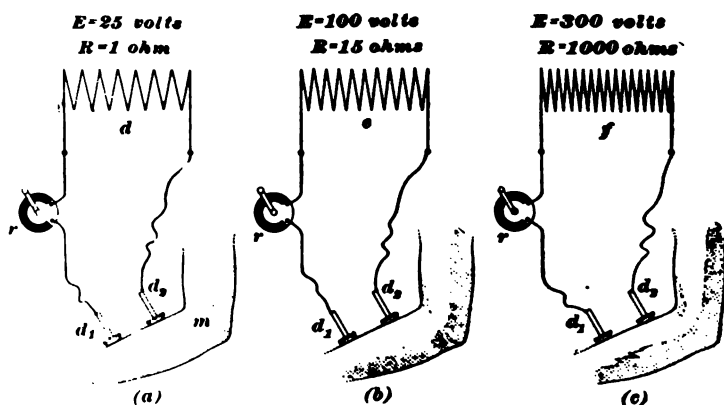
FIG. 30.

and 100 volts; and the finest one *f* of 1,000 ohms and 300 volts. It is clear that the latter is the only one that can be used in the circuits of the highest resistance in order to overcome the latter and cause some current to pass through the circuit. Again, when it is a question of sending relatively slow impulses of high amperage through a circuit, as for instance in the case of muscle treatment, the fine-wire coil would be useless and the low-resistance coil would have to be used. The medium coil of 100 volts would occupy a middle position, sometimes working in one field, sometimes in another. In fact we can suppose a case where all three would be able to accomplish the same results. This has been represented in Fig. 30. Each of the three coils are, in turn, connected with the electrodes d_1, d_2 placed on the arm *m*. In series with the circuit is, in either case, placed a rheostat *r*, by means of which resistance can be added to the 600 ohms through the arm. If now the number of interruptions are maintained at a certain rate, it will be

possible by proper adjustment of the rheostat *r* to send a current through the arm that for either coil will be the same. We have in this instance simply varied the E. M. F. of the secondary coil by selecting a coarser- or finer-wire coil and accomplished the closer adjustment by means of a rheostat.

Many coils are built on the principle of the Dubois-Reymond coil, in which the secondary coil may be moved over the primary coil, either entirely covering the latter or more or less moved out of the field of the same. In the latter case, a very close adjustment of current-strength may be obtained without the aid
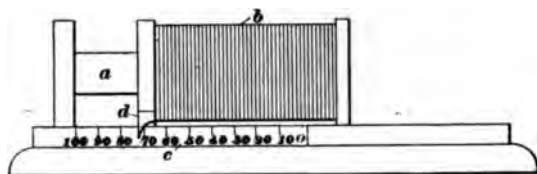
FIG. 31.

of an additional rheostat. Engelmann has made many experiments with coils of this class, a description of which will materially aid in seeing the influence of external resistance; also, the effect of a contact surface and the number of interruptions per minute. To fully understand the following experiment, we give in Fig. 31 a diagrammatic view of the Dubois-Reymond coil. The primary and stationary coil is *a*, *b* is the secondary coil that may be moved backwards and forwards by any suitable means. For the sake of comparison its various positions are indicated on the scale *c* by means of the pointer *d*. The scale is divided into 100 parts, the number *100* indicating complete juxtaposition and *0* meaning that the secondary coil is withdrawn to the end of the primary. While these numbers do not, for various coils, indicate the same values, they aid materially in enabling the operator to reproduce the same effects with one individual coil.

68. The Interrupter as a Current-Regulator.—This means for regulating the current-strength of a secondary coil does not seem to be utilized to a very great extent. The reason for this may be that ordinarily the interrupters are of a more primitive nature, not permitting much adjustment. In many

cases these means may be at hand, but the practitioner has not familiarized himself with the effects that may be produced by varying the position of the contact-screw. As a rule the contact-screw of the interrupter is inserted in a moveable rod, and by moving this either in or out the screw will come in contact either with the end or the middle of the vibrating spring; either position produces interruptions that are materially different in their action on the current-strength through the secondary coil.

The effect of an increase in the number of interruptions per minute is to increase the current-strength in the secondary coil. This holds true up to a certain point, beyond which no increase takes place, but, on the contrary, a gradual diminution that will continue until at a certain point the physiological effect is zero.

For instance, in trying to find the point where the first sensation of the secondary current was felt, the following experiment was made by Engelmann. By using single slow interruptions and sending the current through the upper and lower arm by means of small, high-resistance, metal brush electrodes, the first sensation was felt when the secondary coil stood at *45*, Fig. 31; on increasing the number of vibrations to 150 per minute, the current was felt at *40.5* on the scale; and by increasing the interruptions to 4,000 per minute, sensation was experienced at *34* on the scale.

To produce a muscle-jerk the conditions were somewhat different. The first effect on the muscle was obtained by using single interruptions when the coil stood at *63;* by the slow vibrations at *52,* and the rapid vibrations at *43.5*. By means of a coil of medium current-strength, muscle-contractions were found to take place when the coil stood at *45*, and while the vibrations varied between 45 and 1,000. By increasing the number of vibrations an increase in current-strength was obtained up to 4,000 per minute, sensory nerves ceased to react at 6,500 per minute, and no effect was noticed at 10,000 per minute. The stronger the current through the secondary coil the higher must be the rate of vibration before its effects will cease. In one instance it was necessary to increase the rate up to 28,000 per minute before the current ceased to be felt.

69. Cause of Difference in Current-Strength of Fine-Wire and Coarse-Wire Coils. — It may perhaps appear to some that two coils made up of the same number of turns, but one of coarse and the other of fine wire, should produce the same results. But this cannot be, as in one case the turns occupy a much smaller space and thus, being nearer the primary coil, are in a stronger magnetic field. Likewise, the self-induction in the fine-wire coil is much more intense than in the coarser coil, because the turns are closer together. To test this point Engelmann took two coils containing exactly 528 turns each. The coarse coil, which was made of No. 15 wire had a resistance of .85 ohm; the finer coil, which was made up of No. 40 wire had a resistance of 180 ohms. With the secondary coil at *100* the coarse coil gave, on short-circuit, a current of 25 milliamperes; the fine coil .5 milliampere.

Through a resistance of 50,000 ohms at 3,000 interruptions per minute, with metal brush electrodes of high resistance applied to the upper and lower arm and with the coils in perfect juxtaposition, the coarse coil caused strong, but not painful, contractions, and the contractions at position *50* were without sensation. The fine-wire coil could not be borne at position *100* and was painful even at *75*, but with very slight contractions.

When moist electrodes, 2 square inches in area, were used, the coarse coil caused powerful, but painless, contractions at *70*, while the fine coil caused strong contractions at *40* that were so painful that they could not be borne beyond *50*. The fine-wire-coil current is a more penetrating one and affects the sensory nerves, which the coarse coil affects but little.

70. Effect of Surface Resistance and Electrodes. Surface resistance and electrodes play a very important rôle in electrotherapeutics and will often decide whether a coarse-wire or a fine-wire coil will secure the best results. Judged by the reasons already given, it may be said in general that a coarse-wire coil has its place in cases where the resistance is reduced to a minimum, as for instance by treatment of internal organs, where not only the resistance of the muscular fibers is of the

lowest, but where also the surface resistance is at a minimum. In cases of this kind the current will readily disperse over large areas without causing any disagreeable sensations, but will at the same time reach deep-seated muscles.

The main function of the fine-wire coil is to be sedative or to produce anesthesia. But even these effects cannot be produced unless the surface resistance is of the right character. For instance, if this resistance is high and the interruptions at a moderate rate, the effects will be quite the opposite, they will be irritating. To produce sedative effects the surface resistance should be of the lowest and the rate of interruptions very high.

In an external application to the hand and elbow with high-resistance electrodes, a coarse-wire coil of 1,100 turns and 3.8 ohms' resistance was used in full juxtaposition without causing any particular pain. A fine-wire coil of 11,050 turns and 1,030 ohms' resistance and very far from juxtaposition caused intense pain. When using moist electrodes, the coarse-wire coil at its *0* position gave strong contractions, but the fine-wire coil at *100* was painless and gave but slight contractions.

To show more fully the effect of the surface resistance the following experiment may be quoted. A secondary coil of No. 32 wire, 4,500 feet long and 747 ohms' resistance, sends a current through small metallic brush electrodes of high resistance to the middle and upper arm. The interruptions per minute are 500. At *50* on the scale the currents are intensely painful and unbearable. But substituting moist electrodes having 2 square inches of surface and moving the coils in perfect juxtaposition, the muscles are strongly contracted, but the sensory nerves are not affected.

71. Influence of Resistance of Electrodes.—In studying the sensory effects of faradic currents from coils of coarse, medium, and fine wire, Bordier experimented with the following electrodes:

Carbon	.35 ohm
Solution *NaCl* 12 per cent.	.6 ohm
Solution *NaCl* 4 per cent.	1.4 ohms
Ordinary water	35.0 ohms

    Mixture of water and alcohol 5 per cent. 65.0 ohms
    Mixture of water and alcohol 20 per cent. 86.0 ohms
    Mixture of water and alcohol 50 per cent. 220.0 ohms
    Mixture of water and alcohol 80 per cent. 390.0 ohms

The current in the primary was 1.35 amperes and number of interruptions 104 per second. The coil was provided with a condenser in the primary circuit. The active electrode was placed on the anterior surface of the thigh. The maximum current-strength from each coil was regulated by means of a rheostat in the patient's circuit, and the current-strength required to produce minimum sensation with the different electrodes was noted. The telephone method was used to estimate the current-strength that caused minimum sensation for each electrode.

With the carbon electrode, the sound of the telephone was feeble at the moment of minimum sensation and increased in intensity with the electrodes of sodium-chlorid solutions. The sound was most intense with the electrode of ordinary water. With the electrodes of different solutions of alcohol, the sound decreased as the resistances of the solutions increased. As the sound was loudest with the electrodes of ordinary water at the moment of appearance of minimum sensation, the current strength producing minimum sensation was also greatest. These experiments of Bordier proved conclusively that the resistance of the electrodes influences the sensory effects of the currents from the different faradic coils in a very decided manner, and that when sensory effects are not required an electrode of ordinary water is the most appropriate. If on the contrary the object is to produce marked sensory effects, as in anesthesia, electrodes of very high resistance, as dry sponge or chamois, or of very low resistance, as bare metal, should be employed.

Duchenne observed that when the skin was dry the faradic current caused intense pain before its intensity was sufficient to excite muscular contraction. If dry sponge or chamois is used for electrodes, pain is very pronounced; in this case, the resistance of the electrodes is very high. If metal is used as an electrode, the pain is even greater than when dry sponge or chamois is used; in this case, the resistance of the electrode (bare metal) is very feeble. When a moist electrode—gauze,

chamois, or amadou saturated with water—is used, the cutaneous sensation is very feeble.   An electrode of very high resistance and an electrode of very low resistance act similarly on the nerve termination in the skin.   An electrode of medium resistance acts mildly on the sensory nerves and attenuates painful sensations.

What is here said of electrode resistance with regard to sensory effects in faradic applications is equally true of galvanic applications.   In making galvanic applications to the spine through large gauze electrodes saturated with ordinary water, it will be found that the current-intensity must be diminished to maintain the same sensory effect if the conductivity of the water is increased by the addition of sodium chlorid or sodium bicarbonate.

72. Sensory Effects of Prolonged Excitation.—If a large electrode is placed on the back below the neck and an active electrode 2″ · 2″ composed of fifty layers of surgeon's gauze, thoroughly saturated with water is placed on the flexor surface of the forearm, the sensory effects of prolonged excitation by means of the faradic current from the three standard coils may be studied.   The maximum current from each coil can be regulated through a rheostat in the patient's circuit. Increase the current gradually by removing resistance from the rheostat until the first perception of sensation.   The position indicated by the index on the rheostat should be noted.   The current is then gradually increased until strong muscular contraction is produced.   After 5 minutes of current flow, reduce the current to zero.   With the electrodes in the same position the current is again applied by removing resistance from the rheostat until the first perception of sensation.   If the two positions of the index of the rheostat are now compared, it will be found that to produce minimum sensation in the second case a much stronger current was required, proving that 5 minutes of faradic excitation decreased cutaneous sensibility.   If the experiment is repeated for all three of the faradic coils—coarse, medium, and fine- it will be observed that the rapidly interrupted current from the long fine-wire coil acts much more

vigorously in reducing cutaneous sensibility than either of the
other coils.   The rapidly interrupted current from the medium
coil applied in the same manner for the same time has less
effect on cutaneous sensibility, and the current from the coarse-
wire coil has the least of all.   The explanation of this anes-
thetic action of the rapidly interrupted current from the long
fine-wire coil is to be looked for in the fatigued condition of the
sensory-nerve fibrils in the skin.
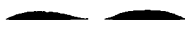
73. Sedative Effects of Coil-Currents.—That both
sensory and motor nerves as well as muscles are subject to
the physiological law of fatigue was demonstrated by Dubois-
Reymond in his investigations of nerve- and muscle-currents.
The so-called current of action or negative oscillation is produced
when the nerve or muscle or gland is stimulated.   Dubois-
Reymond observed that repeated stimulations soon weakened
the deviation of the galvanometer-needle and finally totally
arrested it, which would prove that the nerves could be in reality
fatigued.   This sedative effect of coil-currents on nerve terminals,
whether sensory or motor, is one of the most important proper-
ties of intermittent induced currents.   The practical value of this
sedative property is found in the gradual increase of current-
strength by successive reductions in rheostat resistance until
finally a current-strength is attained that would be simply
unbearable if applied at once in the beginning of the séance.

The production of motor or sensory fatigue by the rapidly
interrupted current from the long fine-wire coil by successive
reductions of rheostat resistance, or successive increases in the
overlapping of sledge coils, is utilized in practical therapeutics
in relaxing contractured muscles and in allaying the various
modalities of nerve pain.   The successive increase of current-
strength permits of the production of profound effects while the
current-strength is always maintained within limits of tolerance.
As the sedative effect cannot be produced at all by the current
from the coarse-wire coil and only very slightly by the
current from the medium coil, it would seem that nerves, both
motor and sensory, are influenced chiefly by variations of
potential and that current quantity has little influence.

Every variety of electric currents has its characteristics of excitation, or wave-form. Every wave-form has two elements, namely, pressure and time. In the present instance the element time does not vary, since the number of interruptions was the same for each current. The difference in wave-form consists not only in the difference in height or E. M. F., but also in the abruptness with which the maximum E. M. F. is attained. The current from the long fine-wire coil has the highest wave-form and therefore the greatest E. M. F. The reduction of cutaneous sensibility by the rapidly interrupted current from the long fine-wire coil agrees with the conclusions of d'Arsonval: Nerves are especially sensible to variations of potential, the quantity of electricity having little influence; for muscles, on the contrary, the characteristic of excitation or wave-form must be lengthened, that is, the time element must be increased in order to give current quantity.

74. Effects of Condenser.—The electric sensibility will vary with any coil, depending on whether or not it has a condenser in the primary circuit and also on the capacity of the condenser. The effect of a condenser in the primary circuit will make it necessary to increase the resistance in the rheostat in the secondary circuit in order to produce minimal sensation; the E. M. F. of the induced current is therefore increased. The sensory effects are not proportional to the capacity of the condenser. The chief advantage of a condenser, however, is in rendering the interruptions regular. The sensory effects of regular interruptions are milder and the sensations are more supportable than when the interruptions are irregular. The capacity of the condenser appropriate for any coil can be determined by ascertaining the greatest resistance in the rheostat through which the current from the coil produces minimal sensation.

For the coarse medical coil a condenser having a capacity of ¼ microfarad is best, and for the fine-wire coil 1 microfarad. An adjustable condenser will make it possible to experimentally ascertain the most suitable condenser capacity for a given coil, and is found when the coil produces minimal sensation through the highest resistance.

GENERAL FARADIZATION.

75. Importance of General Faradization. — Electricity will take its proper place among remedial agents when the members of the medical profession know its therapeutic capabilities as well as they now know those of quinin, iron, and the mineral acids. With a little practice, the technique and the different methods of administering electricity can be easily mastered. The time required for each séance will be amply compensated for by the results, immediate and remote, of a proper course of electric treatment. General faradization has been much inveighed against on the score of its embarrassment to the patient, and the time and trouble to the physician. When the physician is in the presence of the indications for the employment of general faradization, and has faith born of experience in its powers as a curative agent, these complaints do not seem serious. Indeed, a careful survey of other curative agents, medical and surgical, excites surprise that any one could object to electric methods on account of the trouble in technique or the embarrassment of administration.

METHOD OF GENERAL FARADIZATION.

76. Essential Procedure.—General faradization may be given in the water-bath and in the hot-air bath or vapor-bath. It is most often administered by means of a large-sized metallic electrode covered with wash-leather. The operator may hold one electrode in his hand, and, with the other hand as an electrode, apply the current to the patient's body. This latter is a very effective method, and gives the physician complete control over the sensations produced by the current. In these different methods of general faradization, the negative electrode, made of copper, and of large size, is placed beneath the patient's feet or under the gluteal region, and the positive electrode is passed over the motor points of the body. The current should always be applied through a rheostat, and regulated to the tolerance of the patient. If the sponge electrode is used, it is well moistened with a solution of sodium

bicarbonate; and if its surface is well soaped, it will facilitate
its movements over the surface of the body. It is not necessary
to go over the entire body in administering general faradization.
The head, cervical and abdominal sympathetic, also the entire
length of spine, should receive special attention. Bony
prominences are painful, and should be avoided. The first
treatment is tentative, and the susceptibilities of the patient are
noted, in order to regulate dosage of subsequent treatments.
In applying faradization to the neck and head, the wet hand
has many and decided advantages as an electrode. In using
the hand, the sensations of the patient are under control,
and the different motor points of the cervical region are much

FIG. 32.

more easily reached and better acted on than could be done by
any conceivable artificial electrode. The hand may be changed
for the sponge-electrode (Fig. 32) when treating the spinal,
thoracic, and abdominal regions. The lower extremities are
usually sufficiently affected by the electrode applied to the soles
of the feet. The upper extremities may be acted on through
their nerves in the cervical region. On account of the physio-
logical importance of the ciliospinal center, it should be given
special attention in every general faradic treatment. The current
employed does not affect the operator when he uses his hand as
an electrode, except perhaps to produce slight fatigue. Indeed,
it is rather beneficial to the operator than otherwise. Cases are

reported where the muscles of the arm gained in size and strength, due wholly to the use of the hand as an electrode. The use of the hand as an electrode should always be resorted to in applying faradization to the head and neck. The results obtained by the hand-electrode are much better and more agreeable to the patient than those produced by the sponge-electrode. That electricity should always be applied *in locus morbi*, as taught by Benedict, is true only in a limited number of diseases. Local diseases quickly alter the functions of the entire organism. Special attention is given to every local manifestation of disease, while general electrification is used to tone up the system, improve nutrition, and resist morbid processes.

77. Object of General Faradization.—The object of general faradization is to submit all parts of the body, particularly the motor points, to the influence of the faradic current. As a rule, the negative pole is applied to the soles of the feet or to the gluteal region, and the positive pole is applied to the various motor points of the body. If the operator desires it, the poles may be changed and the motor points submitted to the more stimulating properties of the negative pole. When applying the faradic current to important nerve-centers, a weak current is first used, and then gradually increased through the rheostat, to the toleration of the patient. By following this rule, the best results will be obtained when it is desirable to act on centers of special importance. In very feeble or paralytic patients, the negative electrode must be secured to the patient's feet, or placed beneath the coccyx. Young children are treated by placing a sponge-electrode beneath the coccyx, the physician using his own hand as an electrode. This is certainly the best method until the child becomes habituated to the sensations produced by the current.

78. Rhythmic Faradic Stimulus.—The experiments of Debedat, cited in Art. **20,** show very clearly the increased physiological development of muscles submitted to the rhythmic faradic stimulus of 30 interruptions per minute. The same

author proves with equal clearness that prolonged faradic teta-
nization causes physiological atrophy. The great utility of
rhythmic faradic contractions, 30-per minute, when applied to
all the muscles of the body, must appeal to the physician as
one of the most valuable therapeutic agents at his command.
Rapid interruptions, with high electromotive force, producing
tetanus, if properly managed, will render the patient striking
service, and exhibit, in an easily understood manner, the ability
of the operator. If a motor point is submitted to tetanizing
interruptions for a brief duration, fatigued and exhausted mus-
cles are given a feeling of lightness and buoyancy. There
is no increased physiological development, but the *bien être* of
the patient is very much improved. A feeling of muscular weak-
ness and exhaustion may be instantly relieved by a proper
application of a rapidly interrupted current to the different
motor points of the body.

A large number of patients coming to the physician's office
for electrical treatment require an agent whose effects are tonic
and stimulating. It is well known in electrotherapeutics that
alternating currents possess these properties in the most striking
manner. The physician should, therefore, have the therapeutic
properties of these currents firmly fixed in his mind.

79. Important Considerations.—The following points
should be carefully observed in every faradization, local or
general, in the bath or with the usual electrodes:

1. The electromotive force employed, whether high or low.

2. The number of interruptions per minute, whether 30,
150, 2,000, or 10,000.

3. The character of interruptions, whether smooth and even,
or irregular and "jerky."

4. The effects produced on the neuromuscular system, and
the duration of the séance.

80. Many diseases are self-limited, and recovery may
result without any treatment, sometimes in spite of treatment.
This is also true when applied to electricity as it is used in
medicine. The best results, however, will be obtained by the
physician that has a thorough knowledge of the physiology and

therapeutics of the current he is about to use.   Further, to
secure success, he must know how to regulate electromotive
force and to determine the required number of interruptions
necessary in any given case, and to be able to properly time the
length of the séance.   The susceptibilities of the patient and
the varying tolerance of different portions of the body will also
require special study.

TECHNIQUE OF ELECTRICAL APPLICATIONS.

81. **Application of Electricity to the Head.**—When
treating a patient by the method of general faradization, care
must always be exercised in applying the current to the head.
Bony surfaces are always painful to electric applications, and
the head makes no exception to the rule.   For the first few
applications it will be safer for the physician if he grasp the
negative electrode in his left hand and use his right hand as
the positive electrode.   By pressing more or less on the electrode
held in his left hand, the strength of the current applied to the
patient can be very closely regulated—can be increased or
diminished at the will of the physician.   The hand used as an
electrode is kept thoroughly wet, so that in this manner current-
strengths, trying to the physician, will be borne without com-
plaint by the patient.   When the hand is placed in the region
of the cerebellum, the current-strength may be considerably
increased, as this part of the cranium tolerates strong currents.
When the hand is over the cerebellar region, and rapid inter-
ruptions with a high electromotive force are used, flashes of
light and metallic taste are very frequently observed.

82. **Application of Electricity to the Cranium.**
As dry hair is a non-conductor, some means must be taken to
permit the electric current to reach the brain.   In the case of
females, moistening the cranial center, a point midway between
the ears on the summit, will serve to pass a weak current and
accomplish the effects desired.   The cranial center is the
most ·important center in electrical application to the head.
In male patients, the whole head may be moistened with
water and the resistance to the current reduced as much as

possible. In applying faradization to the cranium, the fifth pair, the seventh pair, the cerebral centers, and the muscles of the cranial region are submitted to the influence of the faradic current. There is little, if any, electrolytic action produced, but marked tonic and stimulating effects follow each application. The nearer the alternating current approaches the sine-wave type, the less can electrolytic action occur. In well-marked dissymmetrical wave-currents, there must be some electrolytic action, and this should always be remembered in faradizing the cranium. In using electricity on any part of the body, the physician's intellect should be wholly occupied by the work he is doing; but this becomes emphatic and allows of no exception when electricity in any form is being applied to the region of the head. The application of electricity in any form to the cervical region is worthy of all the attention of which the physician is capable. Through the cervical region pass the pneumogastric and phrenic nerves, and the brachial plexuses; and close to the spinal column on either side is found the chain of sympathetic ganglia. All these important structures can be influenced in their functions by electric currents, particularly when the hand of the physician is used as an electrode. In enumerating the nerve structures of the neck, the large arterial trunks must not be forgotten. These latter, by appropriate manipulation with the hand-electrode, can be contracted or dilated at the will of the physician, and the cerebral circulation directly influenced.

83. Cervical Region.—It is well established in the physiology of electrotherapeutics that rapidly interrupted induction-coil currents increase the vermicular motion of the muscular layer of the arteries, and that when the electric current is flowing in the direction of the normal vermicular motion the flow of the blood-current is increased. When the electric current opposes the direction of the normal vermicular movement, the flow of the blood-current is diminished. In applying the rapidly interrupted current to the cervical region, as part of the treatment of general faradization, the physician has to some extent the circulation of the cerebrum under his control.

Faradization of the spine requires some practice to produce all the effects of which it is capable, and is remarkable for the number of phenomena that it induces. For example, with the sponge well moistened and firmly pressed over the ciliospinal center, the most important center of the spine, the lungs are influenced through the phrenic nerves; the larynx, through the laryngeal nerves; the stomach, through the pneumogastric nerves; and the superior members, through the brachial plexuses. The influence of the electric current, thus modifying the most vital parts of the nervous system, gives a sound physiological basis for its use in the cure of disease. During this application to the ciliospinal center, the sympathetic ganglia are also modified in their functions, and the wide range of their physiology is also utilized in directing and modifying pathological processes. To obtain the full benefits of faradization of the ciliospinal center, the sponge is well moistened and firmly pressed against the vertebræ. Strong currents must also be used.

84. Ciliospinal Center.—With the exception of the perineum, there is no other part of the body where so many nerves may be influenced by a stabile application as the part known as the ciliospinal center. The application of alternating currents to the ciliospinal center is worthy of the most careful attention and painstaking care. Some patients, even with weak currents, are annoyed by a persistent cough, due to stimulation of the laryngeal nerves. Others complain of a feeling of depression, referred to the epigastric region. As a rule, however, the effects produced in all classes of patients are exhilarating, tonic, and sustaining, even from the first application. A proper application to the ciliospinal center is the most satisfactory part of general faradization. The patient usually demands its repetition, and expresses his sense of gratitude for the beneficial effects produced. In treating patients with a thick layer of adipose tissue, extra precautions must be taken to get the current to the center. The sponge should be well saturated in some saline solution, and firmly pressed against the spinous processes. The current is also increased in strength.

In fact, the current is turned on through the rheostat until the patient expresses a feeling of intolerance. Before beginning treatment the surface-area of the ciliospinal center is well moistened with water.

85. The Spine.—After attention has been given to the ciliospinal center, and all the effects produced of which the current used is capable, the application is continued along the entire length of the spine. The sponge is still firmly pressed to the spinous processes; but after the scapular

FIG. 33.

region is passed, the electrode may be applied to the hepatic, renal, and splenic regions, descending to the cauda equina, carefully avoiding the innominate bones. The middle portions of the spine tolerate strong currents, without the least expression of pain or annoyance. The electrode illustrated in **Fig. 33** is often used in making applications to the spine.

86. Genitospinal Center. — Sufficiently trustworthy experiments have already accumulated to justify the assertion that the alternating current acts as effectively on the genitospinal center as it has been shown to do on the ciliospinal center. A study of the physiology of the genitospinal center before an electric application, compared with a study made after an electric séance, leaves no room for doubt concerning the influence of electricity on this center. The skin must be well moistened, the electrodes thoroughly saturated, and the current-strength carried to the tolerance of the patient. Attention to the coil used, its vibrator, and its inducing E. M. F., with a knowledge of the susceptibilities of the patient, will contribute much to the results obtained.

These two centers, the ciliospinal and the genitospinal, are, through the testimony of clinical experience, the most important

parts to be attended to in general faradization. With a well-saturated electrode placed over either of these areas, and a strong current used, the phenomena produced are striking, and will always command the attention of the physician. When the cranium has been submitted to the action of the current, as described, and the anterior and posterior triangles of the cervical region carefully and appropriately acted on, the other two areas commanding attention in general faradization are the ciliospinal and genitospinal centers. It will thus be seen that in a properly conducted séance of general faradization, the entire neuromuscular system is submitted to the tonic stimulating influence of alternating currents. It cannot be made too clear that the results obtained will depend in a large measure on the skill of the operator, on the electromotive force employed, and on the rapidity and evenness of the vibrations. The vibrator ought to be easily and noiselessly manipulated, so that the patient will not become alarmed by any change in technique that the physician may see fit to make.

87. The Thoracic Region.—The organs of the thoracic cavity are little or not at all influenced in their functions by applying the electrodes to the thoracic walls. To influence the thoracic organs, the nerves supplying these organs must be acted on at a distance—in the spine or in the angles of the cervical region. Much good, however, can be accomplished by applying both electrodes to the thoracic walls, or the negative electrode to the feet or gluteal region, and the positive electrode moved over the surface of the thorax. With well-regulated interruptions, the external and internal intercostal muscles, with other muscles attached to the ribs, are increased in physiological development by every faradic application. On account of the anatomical formation of the chest, strong currents are not tolerated, yet currents of sufficient strength to increase physiological development are agreeable to the patient, and in the majority of cases are well borne. In some patients, the hepatic and splenic regions are unaccountably tender, and justify the suspicion that the important organs of these areas are more or less diseased. Faradization of the thoracic walls is

beneficial simply as a muscular stimulant; there is no action produced on the heart or lungs by direct application.

88. The Abdomen.—The anatomical conditions of the abdomen differ greatly from those of the thorax. The conditions of electric conduction are much better in the abdominal than in the thoracic region. The alternating current acts directly on all the organs contained in the abdominal cavity, without any regard to their nerve-supply. The skin is well moistened and the electrodes thoroughly saturated. Adipose tissue is a poor conductor of electricity, and this must be thought of and compensated for, in treating corpulent patients. In corpulent patients, the active electrode is made somewhat larger; it is thoroughly saturated and pressed on the abdominal viscera with as much force as the patient can comfortably bear. The action of alternating currents on non-striated muscle-fibers drops rapidly in diseased conditions, such as paresis, atony, etc., and the direct current is then used. In every application of general faradization, the abdominal viscera should receive a few minutes' attention, and the physician should be particular to bring the organs contained in the abdominal cavity under the influence of the alternating current. The treatment gives tone to the flaccid voluntary muscles at the same time that it stimulates the function and increases the nutrition of the deep-seated organs.

89. The Lower Extremities.—The anesthetic properties of the faradic current, and its important uses in gynecology, do not properly come under the head of general faradization. It has previously been stated that the negative copper plate applied to the soles of the feet causes sufficient electrical action on the lower extremities. If it becomes necessary to extend the application, the patient is requested to stand on the copper electrode while the physician goes over all the motor points of the lower extremities. In this method of application, the hand makes a very serviceable electrode. The tolerance of the external and internal surfaces of the thigh differs widely. There are very few sensory nerves distributed to the external part of the thigh, whereas the shower

of nerves known as the *anterior crural* renders the internal surface of the thigh very sensitive. The physician will best control the effects of the current by holding the negative electrode in his left hand and applying his right hand, well moistened, to the parts selected. By pressing on the electrode held in his left hand, the current-strength can be instantly increased or diminished. While making these applications, the superior part of the body should be well protected by clothing. The physician must always think of the comfort and convenience of his patient.

90. The Upper Extremities.—The upper extremities are usually sufficiently affected by the current when it is applied to the spine or cervical region. It may be necessary in certain cases for the physician to make direct application to the motor points of both arms. In doing this, the object to be attained is kept steadily in view. If tonic vasoconstrictor effects are desired, the interruptions are made rapid, and the electrode simply permitted to make contact, and no more. If physiological development is required in cases of paralysis, slow interruptions (30 per minute) are used, and the application is continued for about 5 minutes. To secure this rhythmic faradic interruption, 30 per minute, a special clockwork mechanism is required. This mechanism is a necessity, when physiological exercise of paretic or paralyzed muscles is the point in view. The faradic battery is not arranged for giving accurately 30 interruptions per minute; and, as the rate of interruptions plays an important rôle in electrotherapeutics, the clockwork mechanism should be attached to the battery for effective work. A rapid rate of interruptions per minute rapidly fatigues the muscles, diseased or healthy, and will, in a short time, cause physiological atrophy, the exact opposite of that which the physician desires to secure.

91. The Hand as an Electrode.—In beginning a course of treatment by general faradization, if no contra-indications exist, it is best to use the hand as an electrode. In this way it is possible to avoid shocking the patient or throwing

him off his feet in applying alternating currents to the
lower extremities. There are certain objections to using the
hand as an electrode—objections on the part of the physician,
and objections on the part of the patient. In the presence of
disease, however, and confronted with the desire to recover,
the objections on both sides, one might think, could be easily
overcome. Without doubt, when applying electricity to certain
portions of the body—to the head, neck, or internal surface
of the thighs—no artificial electrode yet constructed has the
pliability or adaptability of the human hand. When the
patient becomes habituated to the sensations of the current, or
when the physician has the susceptibilities of his patient
completely under control, the sponge-electrode may be
employed, or the use of the hand-electrode continued. The
electrode used will be determined by the individual opinion
of the physician; yet the physician will never regret having
used his hand as an electrode, at least for the first few appli-
cations, particularly when applying electricity to the head, neck,
or inner surface of the thigh.

92. An Average Application.—The tonic stimulating
effect of general faradization can be secured without acting
directly on either the upper or the lower extremities. In the
majority of cases a 1-minute application to the head will suffice,
because it is more sensitive and responsive to the action of the
current, and as a rule is not prolonged beyond this period.
The neck, sympathetic ganglia, and cervical spine occupy the
greater part of the séance; next come the back, abdomen, and,
if necessary, the upper and lower extremities.

An average application may be apportioned as follows:

1. Head, 1 minute.

2. Cervical region, including the cervical spine, 5 minutes.

3. Entire length of spine, including hepatic, splenic, and
renal regions, 4 minutes.

4. Anterior abdominal region, about the same time.

5. The time devoted to the upper and lower extremities will
be determined by the judgment of the physician and the effects
to be produced.

93. The Time Element.—The time necessary for all electrical applications varies but little. General faradization, central galvanization, and static methods all require about the same time. The treatments may be repeated daily, on alternate days, or once a week, according to the diseased condition. Even a faradic or galvanic application for a peripheral affection will be found to consume about the same time as general faradization or a required static application. In the language of Trousseau, "chronic diseases demand chronic treatment." A course of iron will have accomplished little at the expiration of one week. To obtain the full benefits of any ferruginous preparation, several months are necessary. The same is true of electricity given in any form; one or two séances will accomplish very little in the direction of complete cure. Most patients applying for electrical treatment have some chronic malady, and chronic maladies require chronic treatment. No matter what the case, at the end of one month there should be some improvement, and the improvement, however slight, will give encouragement to the patient and justify the physician in continuing his plan of treatment. Daily séances give the best results, and cases present themselves in which treatment twice or even three times daily will be found beneficial. The convenience of the patient and the judgment of the physician will determine the number of séances weekly. It will be well, however, to remember that two or three applications daily increase the efficacy of the treatment and inspire confidence.

RESULTS OF GENERAL FARADIZATION.

94. The results produced by general faradization are both primary and secondary. The primary effects are produced during and immediately after each application. The secondary effects occur one or two days after the application.

95. Primary Effects.—The primary effects of general faradization are very important. They are usually tonic and stimulating in their nature. A feeling of lightness, buoyancy, and *bien être* is the usual result when proper methods are

pursued.   A sensation of malaise, depression, headache, lassi-
tude, is not at all incompatible with permanent good results.
The primary effects produced are largely controlled by the skill
and manipulation of the operator.   Patients, much dissatisfied
with the first application, may return in a few days and express
themselves very much improved.   The relief of pain of various
kinds and the feeling of lightness and buoyancy produced by
the first application will usually inspire confidence.

96. Secondary Effects.—The feeling of soreness and
fatigue so often complained of by patients submitted to general
faradization can usually be avoided by making the first few
applications tentative, and by using the hand as an electrode.
Muscles that have not been used for some time, nerves
semidormant for months, give a pathological reaction when
submitted for the first time to the action of the current and
awakened from their lethargy.   In these cases use the hand
as an electrode, make the séance short, or give massage in a
mild form instead of electricity.   Having once learned the
endurance and constitution of the patient, the current-strength
and the length of the séance may be increased.   Annoying
secondary effects are not likely to occur after the third or
fourth séance.

The secondary effects occur after other methods of electric
administration.   Static sparks, vigorously administered, even to
an apparently robust subject, will, after two or three days,
cause muscular soreness and a general feeling of malaise.
Changes in the physiology of the body are produced by an
electric current that continue to act long after the current has
been broken, or its contact with the body interrupted.   The
results of faradization may be apparent during the first séance;
they may show themselves slowly during the course of treat-
ment, or they may become manifest, for the first time, months
after it has been discontinued.   It may not be out of place to
again state that, no matter what method is employed, some
improvement should be manifest in one month; this will guide
the future conduct of the physician.   If no improvement takes
place in one month, treatment may be discontinued.

97. Results Secured.—What results is a physician justified in predicting when he begins the use of coil-currents in the treatment of disease? First, last, and all the time, alternating currents are tonic and stimulating. They may be made sedative and paralyzing when improperly used, or when indications for sedative paralyzing effects present themselves. With the proper number of interruptions per minute, and the necessary electromotive force, the strength and nutrition of the entire muscular system are improved. This is a clinical fact that has been demonstrated in the laboratory. The experiments of Debedat establish this point beyond a doubt.

98. Insomnia.—Insomnia is a symptom common to many maladies. Sometimes static methods serve best; again, central galvanization has proved itself efficacious. In beginning treatment of this chronic and obstinate symptom, general faradization should never be forgotten. It increases the nutrition of brain and spinal cord, sends richer blood to a fatigued and exhausted stomach, increases the peristaltic action of the intestines, and relieves constipation. The entire muscular system, striated and non-striated, is increased in vigor, the physical forces of the human organism are harmonized, sleep is temporarily, and in the great majority of cases permanently, restored. Cases of chronic constipation are permanently cured after two or three months' treatment. The liver and spleen are acted on by alternating currents applied locally; and this action, added to the tonic stimulating influence on the splenic and hepatic nerves, establishes a *raison d'être* for the wide use of general faradization. Alternating currents may be made to exercise their specific action on the intrapelvic organs, in both the male and the female, without the use of an internal electrode. The effects produced on the organs contained in the pelvic cavity will depend on the electromotive force, and on the smoothness and number of interruptions.

99. Electrolysis and Chemical Action.—It has been shown that alternating currents, whether symmetrical or dissymmetrical, have electrolytic action. They certainly have electrolytic action that needs the physician's attention.

Electrolysis in medicine and chemical action are synonymous, and the physician cannot think of one without explaining the other. Indirectly, then, the alternating current must possess decided electrolytic action. Surely, as has been demonstrated, it increases the strength, size, and nutrition of muscles; and the physician takes it that this is accomplished by increased chemical action. The circulation is increased in activity, interchange between the blood-stream and important viscera is accelerated, metabolism is augmented, elimination of used material is facilitated, and the entire organic physiology has new stamina imparted to it, which continues to act until opposing morbid forces establish an equilibrium.

100. "Modus Medendi" of General Faradization. So far as the physician is concerned, the *modus medendi* of general faradization has very little significance. The fact is that the cerebral and spinal ganglia are stimulated in their nutritive processes; whether this stimulation is due to increased supply of blood or whether the alternating currents act directly on these nerve-centers is not yet definitely determined. All through the physiology, technique, and therapy of alternating currents, tonic stimulating properties were always kept in view. Applied to the surface of the body, and acting on the terminal sensory nerves, this tonic stimulating property of alternating currents holds a very prominent place in the treatment of disease. It is well known that any impression—mechanical, chemical, thermal, or electrical—made on the terminal sensory nerves is carried to the central ganglia, where it is capable of modifying function or even producing organic changes. The wide surface covered by the positive electrode in general faradization must necessarily modify the function, and, if frequently repeated, changes the organic structure of the basal ganglia in a large section of the central nervous system. Of course, in hysteria and chorea and allied disorders, the object is to modify functions in central and spinal centers. But there are maladies in which the object most desired is organic change in the basal ganglia. Here, general faradization, properly applied and frequently repeated, will not prove disappointing.

101. Organic Lesions.—In spinal sclerosis, in cerebro-spinal sclerosis, in locomotor ataxia, and in all nervous maladies with well-defined organic lesions, any agent capable of causing structural changes, if applied during the initial stage, should cure or at least arrest the pathological process. The same effects are obtained with static methods with less trouble, but many physicians that have not a static machine may be the owner of a good therapeutic induction-coil. The additional trouble in application is of little moment when the ultimate results to be obtained are kept in view. When counter-irritation and surface stimulation are desired, a dry brush-electrode is used. The physician wishes to produce, over an extended surface, the ordinary action of a capsicum plaster. This impress made by the peripheral electrical irritation travels along the sensory nerves to the centers in the spinal cord; it is then either reflected to some organ in direct nervous connection or it travels through the spinal column upward to the cerebral center. It then exerts its specific action on the cerebral center, and modifies functionally the organs in direct connection with these centers. The physiological stimulation thus initiated continues long after the current of electricity ceases to flow.

102. Permanency of Cure.—The permanency of a cure by electric methods has been widely discussed. A large pro-portion of cases treated by electricity, or that apply for electric treatment, must be classed among those that feel better one day and worse the next. In all these cases, a judicious selection of current, applied with proper care and *lege artis*, and for a sufficient length of time, will effect a permanent cure. After a course of electric treatment, even the most careful possible, relapses may occur. In this case, the course of treatment, more or less modified, should be continued until all symptoms of disease disappear. After any course of treatment—mechanical, surgical, or medicinal—relapses are liable to occur, and electric methods offer no exception to the general rule. The disease should be thoroughly studied before treatment is begun; the form of current appropriate to the pathological condition

carefully considered; and the dosage, the rate and character
of vibrations, and the length of the séance, regulated to suit
the symptoms and susceptibilities of the patient.

GALVANOFARADIZATION.

103. By **galvanofaradization** is meant the simultaneous
application, through the same electrodes, of the two forms of
dynamic electricity—the galvanic and faradic currents. The
negative pole of the galvanic current is connected with the
positive pole of the faradic current, in which case the positive
pole of the galvanic becomes the positive pole for the combined
currents and the negative of the faradic becomes the negative
for the combined currents. The characteristic of excitation,
or wave-form, of galvanofaradic currents are illustrated in
Figs. 15–20. These wave-forms must be understood by the
student in order to comprehend the physiological effects of both
currents in their various combinations. A single rheostat
suffices to regulate both currents.

The sensory effects of both currents combined differs from
that produced by either current used separately.

104. Motor Nerve and Striated Muscles. — Motor
nerves and muscles respond more energetically to the galvano-
faradic current, the battery and coil being in series, than when
stimulated by the coil-current alone. When, however, the
currents are connected so that they flow in opposite directions
instead of the same direction, the action on motor nerves and
muscles is much feebler than when the induced current is used
alone. The characteristic of excitation for this current is illus-
trated in Fig. 19. To this excitatory action on motor nerves
and muscles must also be added the electrolytic effects of the
direct current.

105. Non-Striated Muscles. — With regard to thera-
peutics, one of the most interesting physiological effects of
galvanofaradic applications to non-striated muscles is that the
effects of faradization with the rapidly interrupted current from
the long fine-wire coil can be exactly duplicated by combining

in series the coarse-wire coil with the galvanic current. Faradi-
zation with the coarse-wire coil used alone produces no effect on
the musculature of the intestines; but if a continuous current
of 2 or 3 milliamperes is introduced into the faradic circuit,
energetic contraction of the circular fibers of the intestines is at
once produced.

Effective faradization with the current from the long fine-wire
coil is very painful for patients, whereas galvanofaradization,
using the coarse-wire coil, produces the same motor effects and
is at the same time readily supported.

106. Sensory Nerves.—Waller and de Watteville have
demonstrated that the electrotonic phenomena are the same in
both sensory and motor nerves. A condition of increased irri-
tability is produced in the sensory-nerve terminals beneath the
cathode of the direct current, and a condition of decreased
irritability beneath the anode. The sensory effects of galvano-
faradization undergo the same variations as the motor effects
and are more intense than when the faradic current is employed
alone. The physiological effects of galvanofaradization are
interesting to observe when the two current sources are connected
in parallel and the active electrodes are the anode of the galvanic
and the cathode of the faradic current. However lively may be
the sensation produced by the faradic excitation alone, it is easy
to entirely suppress it by continuing the galvanic current in
opposition and increasing gradually its intensity.

Both currents in opposition are frequently used in the treat-
ment of neuralgia in order to produce the anelectrotonic effects
of the direct current and the revulsive effects of the coil-current.
In the treatment of neuralgia, de Watteville combined the
currents in series to obtain the catelectrotonic and nutritive
effects of the direct current and the revulsive effect of the
coil-current.

<hr/>

THERAPEUTIC INDICATIONS.

107. Galvanofaradization is employed with success when-
ever the galvanic and faradic currents are simultaneously
indicated. In paralysis and muscular atrophies where strong

excitations are required, rhythmic galvanofaradization obtained by combining the galvanic and faradic currents in series should be employed. Irritability is increased by the catelectrotonic action of the direct current, and the closings and openings of the direct current together with the faradic produce the required excitations. At the same time the cataphoric and electrolytic properties of the direct current act with the motor effects in increasing the nutrition of muscles and combating atrophy. Bordier reports a case in which rhythmic galvanofaradization for 10 minutes three times a week caused considerable hypertrophy of the muscles of the arm and forearm. He recommends rhythmic galvanofaradization in myopathic atrophies in the following manner: The positive pole of both currents is placed on the motor point of the nerve supplying the diseased muscles and the negative pole of both currents is applied labile over the diseased muscles. The treatment should be continued with occasional interruptions of 2 or 3 months for a period of several years. Each séance is of 10 or 15 minutes' duration and the maximum strength of the galvanic current should not exceed 8 milliamperes. When other electrical applications have failed in the treatment of neurasthenia, Hirt recommended rhythmic galvanofaradization with high current-intensities applied to the inferior extremities. The muscular contractions thus produced are at first badly supported but the therapeutic results are at times surprising.

108. Galvanofaradization seems to be especially serviceable and is much recommended at the present time in the treatment of non-striated muscle-fiber. Erb particularly recommends galvanofaradization in cases of dilatation of the stomach with atony and feebleness of that organ and in intestinal occlusion due to accumulation of fecal matter, and in chronic constipation due to intestinal atrophy.   In stomachic and intestinal affections galvanofaradization is the treatment of choice.

M. M. Laquerrière and Delherm have recently published very happy results from the use of galvanofaradization with the current from the coarse-wire coil in cases of chronic constipation.   The current from the coarse-wire coil, combined with

the direct current in series, has about the same effect on non-striated fiber as the rapidly interrupted current from the fine-wire coil applied alone, but has not the inconvenience of the latter. The sensory effects of galvanofaradization, using the induced current from the long fine-wire coil, are reduced to a minimum by the use of electrodes having large surface area.

109. Rockwell recommends the employment of galvano-faradization in the treatment of exophthalmic goiter, but there is diversity of opinion with regard to the electric modality best adapted to its treatment. Some electrotherapeutists, Vigoroux for example, recommend the faradic current alone; others, among whom Eichhorst is the most important, recommend the galvanic current; while still others, as Larat, use both succes-sively during the same séance. Other electrotherapeutists recommend the electrolytic introduction of iodin, some from the negative, others from the positive pole, as the treatment most appropriate for exophthalmic goiter. The way out of the diffi-culty lies in a close study of the symptomatology of exoph-thalmic goiter and in a judicious selection of the physicochemical and physiological properties of the various electric modalities.

According to Rockwell the symptoms of exophthalmic goiter are more readily ameliorated by combined than by single elec-trization. If the disease is due to the sympathetic, galvano-faradization will act more energetically on the vasomotor phenomena than either current alone. The physiological effects of the combined currents on non-striated muscle-fiber explain the favorable action of galvanofaradization in certain cases of exophthalmic goiter. If exophthalmic goiter is due to disease of the thyroid (hyperthyroidation) the combined method ought to be and is, according to Rockwell, more effective than either used alone or successively during the same séance.

All electric modalities will relieve certain conditions of pain, one succeeding where the other failed, and vice versa. The pain that is not increased by pressure, and particularly if pressure affords relief, is likely to be benefited by the faradic current, or sinusoidal current, or by any of the high-potential manifesta-tions of electricity; while painful parts, sensitive to pressure,

with the exception of the hyperesthesia of hysteria, are as a
rule affected more favorably by the galvanic current. According
to Rockwell, the combined use of the galvanic and faradic
currents possesses no advantages over either current used
separately in the treatment of these conditions. He attributes,
however, special value to the combined use of both currents in
the treatment of spasmodic conditions; urethral spasm, spasm
of the pharynx, and cases of facial spasm yield more promptly
to galvanofaradization than to single electrization with either
the galvanic or coil-current. Galvanofaradization, on account
of the combination of physiological properties that it represents,
namely, motor, electrotonic, cataphoric, electrolytic, possesses
real advantages over either current used separately when the
therapeutic indications require its use.

110. Poore's Experiments.—The classic experiments of
Dr. G. V. Poore, demonstrating the property of the direct
current to increase the enduring powers of striated muscles, is a
clinical proof of the value of both currents used at the same
time. It is evident that if the direct current increases the
enduring powers of skeletal muscles, the séance of general
faradization or local faradization may be prolonged when aided
by the simultaneous use of weak galvanic currents.

Doctor Poore's experiments were made for the purpose of dem-
onstrating (a) the effect of direct currents on fatigued muscles,
(b) the effect of direct currents on the power of muscles.

EXPERIMENT 1. He instances the case of a patient that was able to
hold out his arm horizontally with the weight of 17 ounces in the palm
for 4 minutes, and then complained of great pain, fatigue, and inability
to go on, but was relieved of the pain and fatigue at once by the passage
of a direct current in a descending direction along the arm.

EXPERIMENT 2.—To demonstrate the effect of a direct current on the
power of muscles, the person experimented on squeezed a dynamometer
eight times at intervals of 10 seconds, with an average of 48½ pounds for
each squeeze. With the aid of a direct current, eight more squeezes
were made, giving an average of 59½ pounds. The last series of squeezes
were 8 minutes after the first. The current-strength passed was never
sufficient to cause muscular contraction.

111. Leduc's Experiments.—A digression may be
made here to direct attention to the strikingly interesting

phenomena recently observed by Leduc in dogs and rabbits submitted to the influence of rapidly interrupted currents of low voltage. In these experiments Leduc employed the direct current from 20 storage-cells, or an equivalent number of ordinary chemical cells, and the current was interrupted from 150 to 200 times per second. The head of the dog was shaved and covered with absorbent cotton saturated with a 1-per-cent. solution of sodium chlorid; this was covered by a metallic plate in communication with the cathode of the current-source. The anode, which was arranged in the same manner, was on the back at its posterior portion, which was also shaven. The interrupter was now started and the cells introduced rapidly by means of a cell-selector until the current reached an intensity sufficient to tetanize all the muscles of the body. The animal then fell on its side and respiration ceased; the E. M. F. was progressively diminished until respiration was reestablished, which occurred in both dogs and rabbits at a voltage varying from 16 to 30 and at a rate of flow of 2 milliamperes for the interrupted current and 22 milliamperes for the continuous current, the interrupter being closed. During the period of contraction, both feces and urine passed involuntarily. When respiration was established, the heart acted normally but the animals remained on their side completely immobile; all the skeletal muscles were in a state of complete relaxation, and if the animal was lifted up by seizing folds of the skin, it was completely inert. It could be pinched, pierced with needles, or cut, but it manifested no reactions, made no cry, nor made any movement of defense or flight. The cerebral functions were suppressed and the animal was in a profound sleep and a state of complete anesthesia.

This electric cerebral inhibition may be maintained for a long time. Several animals have been put to sleep at different times for periods of more than 2 hours without the least inconvenience to their health. As soon as the current is discontinued the awakening is sudden, and the animal moves its limbs and jumps joyously around. There are no after results, no vomiting, the animal appears in perfect health. If the E. M. F. is increased very slowly and gradually, clonic convulsions precede

sleep; there is a period of agitation analogous to that produced
during the administration of chloroform.   It is more difficult
to produce sleep in this way and it seems somewhat more
painful to the animal.   By means of these currents applied to
man, all the muscles of an arm or leg may be contracted
without producing any pain.   If the cathode is placed on a
superficial nerve, the median above the wrist for example, a
creeping sensation is produced beneath the electrode and also
absolute and complete anesthesia of the whole region supplied
by the nerve peripheral to the electrode.   If the individual
experimented on has his eyes closed, he may be pinched,
pierced with pins, or cut, without feeling anything in the area
influenced by the current.   Evacuation of the intestines and
bladder invariably accompanied these experiments on rabbits
and dogs, and this without including the cerebrum in the
circuit.   On this account Leduc suggests the use of these
currents in the treatment of gastrointestinal atony.   The most
interesting property of these intermittent currents of low voltage
is certainly the production of sleep and general anesthesia.
Alternating currents of low voltage do not produce these results.

From these experimental researches of Leduc we learn that
intermittent currents of low voltage applied to animals produce,
without pain, instantaneous and complete inhibition of the
cerebral hemispheres, the cardiac and respiratory centers
remaining intact.   The sleep is regular and tranquil and may
be prolonged for hours without inconveniencing in any way the
animal's health.   Directly the circuit is closed the animal
awakens.   To us, there does not seem to be in the whole range
of electrophysiology phenomena more important in their physio-
logical significance or more suggestive in their therapeutic indi-
cations than those observed by the veteran electrotherapeutist
of Nantes in dogs and rabbits submitted to the influence of
rapidly interrupted currents of low voltage.   These remark-
able experimental researches of Leduc must dissipate defi-
nitively whatever lingering doubts may have existed with
regard to the capacity of the direct or galvanic current applied
percutaneously to effect in a direct manner the cerebrospinal
nervous system.

SINUSOIDAL CURRENT.

112. D'Arsonval introduced the **sinusoidal current** into electrotherapeutics in 1893. The apparatus from which it is derived is growing steadily in favor, owing, to a great extent, to its simplicity and the ease with which it is manipulated. The real cause of its widespread use, however, is its wonderful influence over the symptom pain and its capacity to modify the nutritive processes of animal life. The sinusoidal current has a direct action on the nervous system of vegetative life—on the great sympathetic, independent of its action on the neuromuscular system. With low frequencies applied to motor points, it produces energetic, undulating, painless contractions. With
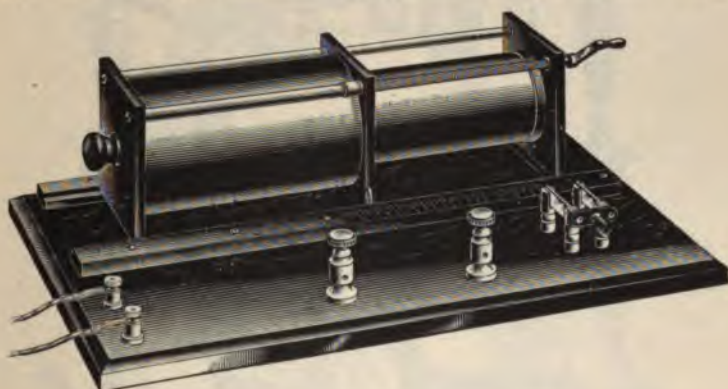
Fig. 34.

Sinusoidal Apparatus for Alternating Current.

high frequencies, tetanic contraction is produced, which lacks, however, the cramp-like sensation caused by the galvanic and faradic currents. Both as an excitant and sedative to contractile tissues, sinusoidal currents have a wide range of use.

113. Sinusoidal Apparatus.—For physicians who have the alternating current in their office, a very efficient sinusoidal apparatus has been arranged in the following manner by Gautier et Larat: The current is taken directly from a 110-volt alternating current with a 30-candle-power lamp interposed as a

resistance.   The current is then conducted directly from the lamp to the primary of an induction-coil.   The current used in the bath is taken from a secondary coil constructed on the Dubois-Reymond type, Fig. 34.   In this arrangement the frequency of the street-current cannot be changed.   The current-

FIG. 35.
Kennelly Sinusoidal Apparatus.

strength is regulated by the degree in which the secondary coil overlaps the primary.   The Kennelly sinusoidal apparatus is very convenient and serviceable, Fig. 35.   For its use the 110-volt direct current is required.   Another sinusoidal apparatus now in very general use is manufactured by the McIntosh Battery and Optical Company, Fig. 36.
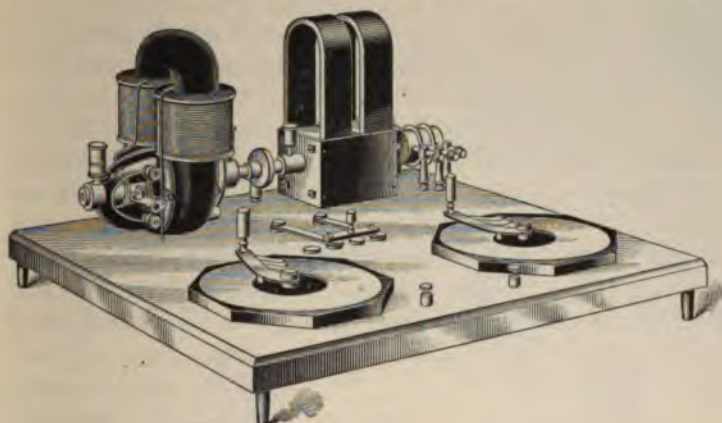
FIG. 36.

McIntosh Sinusoidal Apparatus.
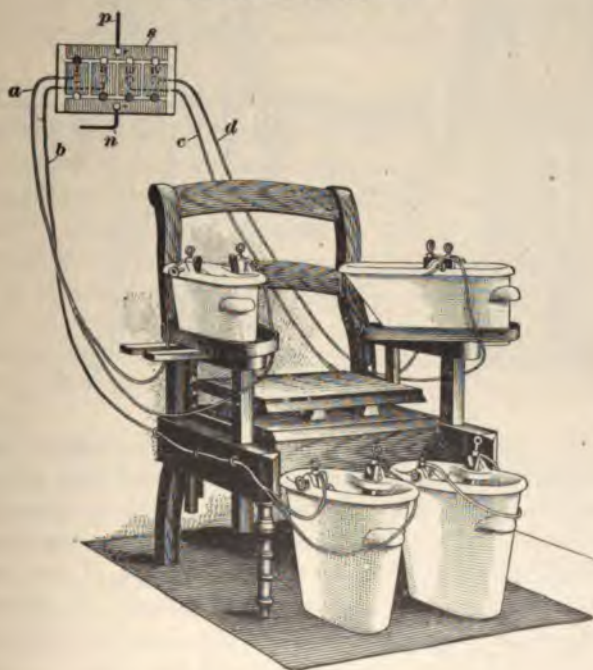
FIG. 37.

The Four-Celled Electric Bath by Doctor Schnée.

114. The general bath, as a means of administering the sinusoidal current, necessitates disrobing.   This is somewhat inconvenient and requires some time.   A very efficient and convenient substitute for the general bath is the bath with four electrodes, as illustrated in Fig. 37.   The patient is placed in a chair, the seat of which may be adjusted to suit the size of the patient.   There are four separate cells, one for each of the arms and legs, each having two electrodes.   The conductors a, b, c, d from each of the cells are connected to separate plates I, II, III, IV on the switchboard S, shown enlarged in Fig. 39.   Each of
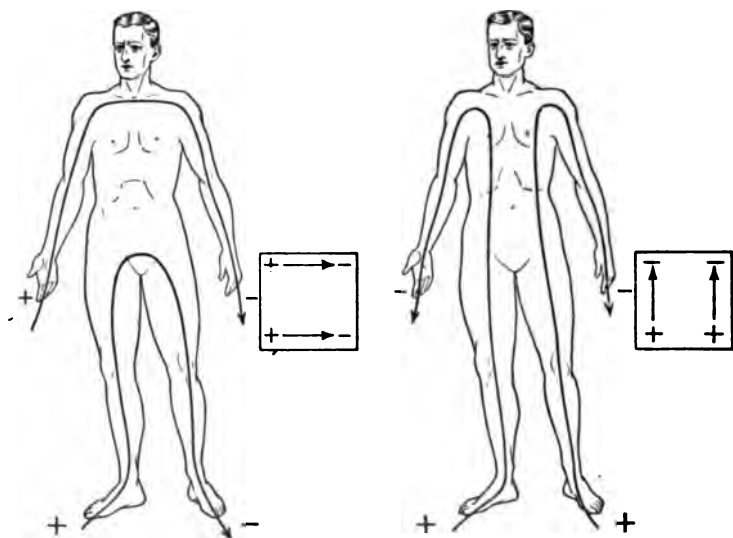
Fig. 38.

these plates may be connected either with the positive strip A or the negative strip B, the first being connected with the positive conductor p and the latter with the negative conductor n. For the purpose of making these connections, the switchboard is provided with the holes a_1, b_1, c_1, d_1 and a_2, b_2, c_2, d_2 into which any of the plugs P_1, P_2, P_3, P_4 may be inserted.   As shown in the illustrations, the plug P_1 connects the plate I with the positive strip A, and plugs P_2, P_3, P_4 connect the plates II, III, IV with the negative strip B.   These four plugs may be rearranged to suit any requirement.

Fig. 38 shows the direction taken by the current, according to the disposition of the current-terminals. The electrodes used in applying the faradic current serve also in the therapeutic uses of sinusoidal currents. Enclose a bipolar vaginal electrode in the palm of the hand, and, with the sinusoidal current of high frequency, observe the effects produced as the current-strength increases to the point of toleration. This experiment will suggest many

FIG. 39.

Switchboard.

therapeutic uses of the sinusoidal current in the painful and congested conditions of the genito-urinary tract.
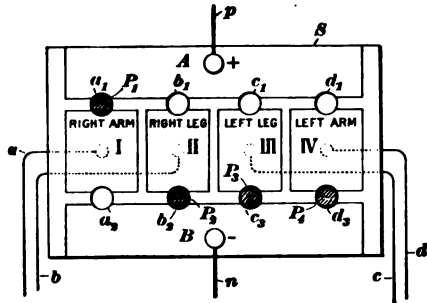
115. Physiological Effects.—With regard to the **physiological effects** of sinusoidal currents, there are two principal factors to be considered—the duration of each wave and its maximum E. M. F. These two values constitute its waveform or characteristic of excitation. The increase and decrease of potential in the sinusoidal wave is gradual and uniform, and it is to this feature of the current no doubt that its peculiar action on motor and sensory nerves is due. Continuity and regularity characterize the sinusoidal wave-form, whereas interruptions and irregularities characterize that of faradic currents.

The faradic wave-form differs from the sinusoidal in the following features: (1) The E. M. F. of the faradic current of opening is much higher than that of closing. (2) The positive and negative waves are not equal. (3) The positive wave is not a prolongation of the negative wave; there is a certain interval between the two. While these two currents are alternating induced currents, they do not present the same wave-form, and consequently excite in a different manner both motor and sensory nerves.

To understand the characteristics of the sinusoidal current obtained from the apparatus of d'Arsonval, Fig. 40, three measures are necessary, namely, those of voltage, amperage, and frequency.   A voltmeter in the field circuit gives the voltage, a tachometer placed on the axis of the dynamo gives
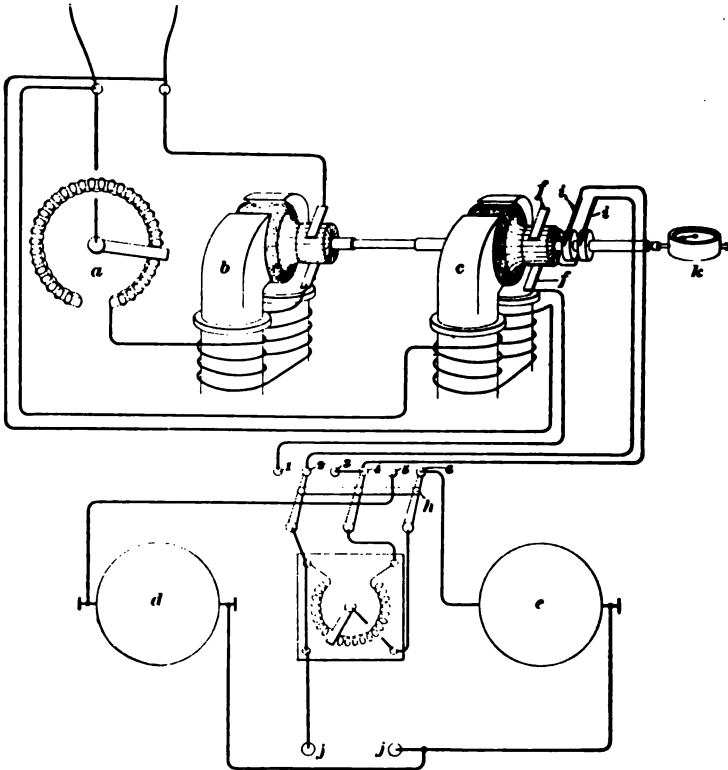
FIG. 40.

(a) *Rheostat;* (b) *Motor;* (c) *Transformer;* (d) *Milliammeter in Undulating Circuit;* (e) *Milliammeter in Alternating Sinusoidal Circuit;* (f, f and i, i) *Contacts;* (h) *Triple Switch or Current-Selector;* (j, j) *Binding-Posts;* (k) *Tachometer.*

the frequency, and a milliammeter placed in the alternating sinusoidal circuit gives the amperage.   From this apparatus of d'Arsonval two types of induced currents are derived—one alternating and the other direct.   The direct, or undulating, current is a periodic induced current having the sinusoidal form, but

it does not change its direction. The E. M. F. of the undulating current increases gradually from zero to maximum and then returns in the same manner to zero to recommence its variations. See Art. **70,** *Magnetism and Electromagnetism.*

When applied to the human organism both waves of the alternating sinusoidal current, that in the positive as well as that in the negative direction, produce similar and equal effects within the tissues. As there are two waves and therefore two excitations in each period, the term frequency would be more significant to physicians if expressed in the number of excitations per second. For example, instead of saying a frequency of 50 per second it would be more expressive of the action of the current to say 100 excitations per second. Applied locally, the sinusoidal current causes mild and wave-like muscular contractions; if the number of excitations is sufficiently high, tetanic contraction is produced, but not so abruptly as with the faradic current.

116. The chief advantage of the sinusoidal current over the current derived from the secondary of the induction-coil is the uniformity in its rate of change. When it is desired therefore to excite vigorous muscular contraction of either voluntary or involuntary muscles, the sinusoidal is the current par excellence.

An interesting point to notice is that the sinusoidal current causes energetic contraction of non-striated muscles, whereas in certain cases it is without action on striated muscles. This observation has been made by d'Arsonval, and is of importance not only in physiology but also in electrotherapeutics. On account of the very regular variation of its E. M. F., the sinusoidal current does not produce painful sensation in the sensory-nerve terminals when the number of excitations per second are **few: it acts** on cutaneous sensibility much like the galvanic **current, and** is not abrupt like the faradic. In a general appli-**cation, as** in the hydro-electric bath, the sinusoidal current has **a decided** action on the nutrition of tissues. According to **d'Arsonval,** Gautier, and Larat, the absorption of oxygen by **the blood** corpuscles is increased 25 per cent. In chronic

congestion of the different organs of the body, a marked diminu-
tion of their size is observed after a course of sinusoidal baths.
The importance of this action in cardiac and hepatic conditions
is obvious. The secretion of urine is also considerably increased.
The current serves to stimulate the muscles of the peripheral
capillaries, which are paretic from distension. This energy
imparted to the peripheral circulation gives new vigor and tone
to the central organ of circulation. At the present time no one
questions the capacity of sinusoidal currents to relieve painful
conditions and to influence favorably the nutritive processes of
animal life. These currents act on the nutrition of tissues
without producing muscular contraction.

**117. Cause of Physiological Effects of Sinusoidal
Currents.**—According to Larat, the physiological effects of the
sinusoidal current are due to a direct action on the nervous
system of vegetative life, independent of its action on the neuro-
muscular system, which may, however, in a secondary manner
increase the direct effects of the current.

A more likely cause of the influence of these currents on
general nutrition is found in the recent experiments of Ayrton
and Perry and of Maneuvrier and Chapuis on the movements
of ions due to alternating currents. These authors have demon-
strated that when electrolysis takes place in a voltmeter, for
example, the positive and the negative ions appear at the same
time on each electrode and that the conditions that increase
electrolysis are a low frequency and high voltage. In order to
determine if displacement of ions took place in the human
body, M. Labatut experimented on a patient in a hydro-electric
bath containing nitrate of pilocarpin. The frequency of the
current passed through the patient in the bath varied from
6 to 120 periods per second; the E. M. F. was 26.7 volts. The
physiological effects of pilocarpin on the sudoriferous glands
were manifested simultaneously at both electrodes. The effects
on the sudoriferous glands were most marked for the low fre-
quencies, and decreased gradually, as the frequencies increased,
without however altogether ceasing, even for the highest fre-
quencies of which the apparatus was capable. Since the ions

appeared at both electrodes there must have been in the interpolar area, that is in the tissues, a displacement of ions, and consequently an exchange of ions between the different tissues, each cell giving to the following cell what it received from the preceding. These exchanges within the tissues modify the chemical composition of the tissues, even though the ions are not liberated within the tissues, being simply displaced. This movement and displacement of ions by means of the sinusoidal current is evidently the cause of the increased respiratory capacity observed by d'Arsonval and confirmed in therapeutic applications.

118. Nutritive Action of the Sinusoidal Current. The nutritive action of the sinusoidal current has many important therapeutic indications; its power, to allay pain, however, is not less important. It is perhaps more important in this way than the rapidly interrupted current from the long fine-wire coil of the physician's induction-apparatus. Apostoli and others have borne strong testimony to the fact that the greatest success they have attained by this form of current has been in allaying the pains that occur in connection with the pelvic organs. The pains caused by uterine inflammation, pelvic cellulitis, ovaritis, salpingitis, and congestion are quickly relieved by it. Neuralgic pains are relieved and those of spinal irritation. This form of current is equally efficacious in painful conditions of the rectum and bladder. The technique of its application in all these different conditions is similar to that of faradic currents. Sluggish circulation is responsible for many cases of sexual frigidity in both sexes. It is claimed that 80 per cent. of impotents suffer from prostatic congestion, hyperesthesia of the deep urethra and weakening of the muscles that govern ejaculation, resulting in premature emissions, a premature want of power. The remarkable action of the sinusoidal current on non-striated muscle-fiber and pheripheral circulation should be remembered in these conditions, and applied locally to give vigor and tone to the parts affected. The value of the sinusoidal current in gynecology is generally conceded, and we believe that when the simplicity of its

technique and the range of its physiological properties are more generally known, the rectal and genito-urinary surgeon will employ it as frequently and effectually as the gynecologist.

119. The Undulating Current.—It will be remembered that this current has an electric wave, starting from zero, increasing in intensity until it reaches the maximum, and then returning to zero in the same manner to recommence its variations in the same direction. This current is derived from the apparatus of d'Arsonval, Fig. 40. Its wave does not change direction, as happens in the sinusoidal alternating current. The undulating current combines, therefore, the effects of the galvanic current with those of the interrupted current. As its electrical wave is always in the same direction, it has electrolytic properties, feebler however than the galvanic, and it is at the same time less irritating and better tolerated than the faradic current. The characteristics of this current were first described by Apostoli and he applied this new electrical method to therapy in general and to gynecology in particular. In general applications this current has not been much employed; in local applications it has been utilized to combat pain, congestion, chronic arthritis, endometritis, subinvolution, periuterine exudations, and ovaritis.

The undulating current is employed in two different manners: (1) The active electrode is covered with wet cotton and inserted into the vagina: (2) the active electrode consists of a uterine sound of platinum introduced into the cavity of the uterus or the cervical canal. In both cases the indifferent electrode was formed of a cake of clay applied to the abdomen. Compresses of surgeon's gauze serve equally well. The duration of each séance was 5 minutes daily for vaginal applications and every 2 days in intra-uterine cases. The smallest dose varied from 10 to 25 milliamperes, 1,800 to 2,500 periods per minute. The least voltage was from 10 to 25. In ordinary cases, according to Apostoli, the indications are generally the same as for the galvanocaustic—the positive for non-congestive and the negative for congestive cases. The applications were always well borne, and they prove that women prefer the undulating

current to the galvanocaustic and faradic. This current may be regarded then as another remedy in the conservative treatment of uterine diseases.

120. Galvanosinusoidal Current. — When for any reason it is desirable to increase the amperage of the sinusoidal current, this may be accomplished by connecting the negative pole of the galvanic with one pole of the sinusoidal apparatus; the rheophores leading to the patient are attached to the other two poles. The wave-form of the galvanosinusoidal current is illustrated in Fig. 22. The magnetic field of the various sinusoidal apparatus is produced either by permanent magnets or electromagnets. When the magnetic field is produced by a permanent magnet, the galvanic current should not be combined with the sinusoidal, because the permanent magnets are demagnetized by the direct current. It is necessary, therefore, in combining these two currents to have the magnetic field produced by an electromagnet. In using the galvanic current combined with either the faradic or sinusoidal it is important to convince oneself that both currents are in reality acting within the tissues.

Concerning the action of the faradic or sinusoidal current in these combinations there is no doubt; the muscular contraction produced by them is evidence of their action. The galvanic current, however, is silent in its cataphoric and electrolytic effects. That it produces its well-known effects in these combinations may be demonstrated as follows: Take a hard-boiled egg, with the shell off, and plunge into it two pieces of copper wire that are attached to the tips of the conducting-cords of the galvanofaradic or the galvanosinusoidal current. On the galvanic side use 20 milliamperes without any interruptions. In the course of 3 or 4 minutes at the negative pole the electrolytic action has already softened the egg around the copper wire, which is falling out of its own weight. At the same time at the positive pole will be seen the familiar green oxychlorid of copper and the wire is adherent to the substance of the egg.

HYDRO-ELECTRIC METHODS.

ELECTRIC BATH.

INTRODUCTION.

121. Water as an Electrode.—Devices that serve as an intermediary between an electric source and the human body in supplying the necessary contact surfaces and possessing the required conductive properties are called **electrodes.** Ordinary water at a temperature of 98° possesses the required conductive properties, and as water adapts itself to all the contours of the body, whether on the surface of the body or in the cavities of its interior, it must be regarded as the ideal electrode. From the experiments of Bordier, Art. **71,** we learn that electrodes of very high resistance, as dry sponge or dry chamois, and electrodes of very low resistance, as metallic electrodes, behave in about the same manner, and that they cause very painful effects before the current-intensity is sufficient to cause muscular contraction. Bordier has demonstrated that the sensory effects are least when the conductivity of the electrode is that of ordinary water at a temperature of 98°. When the conductivity of the electrode is increased beyond that of ordinary water at a temperature of 98°, as is the case when sodium chlorid is added, the sensory effects with the same current-strength are much more marked. If, on the other hand, the conductivity of the electrode is less than that of water at a temperature of 98°, as when alcohol is added to the water, the sensory effects are also increased. It is therefore evident that in order to employ the higher current-intensities with a minimum of sensory effects, ordinary water at a temperature of 98° is the proper electrode to select. This adaptability of water to the scientific requirements of electrodes, both as regards their conductivity and their capacity to make close contact with body surface, whether external or internal, gives to **hydro-electric methods,** whether local or general, internal or external, therapeutic value of the first order.

In the general electric bath, as ordinarily employed, part of the current goes through the patient immersed in the water, the other part passes through the water from electrode to electrode, and therefore has no therapeutic value. The percentage of current that actually traverses the tissues of the patient will be governed in each case by the relative conductivity of the patient's tissues and that of the water in which he is immersed. The conditions are changed when the current is applied to the patient by means of local baths, as in the 4-cell bath of Doctor Schnée, Fig. 37. In this case disrobing is not necessary and the entire current must traverse the patient's tissues, as there is no other conducting medium.

122. The hydro-electric bath may be applied to individual parts of the body, as to an arm or a leg, in which case the indifferent electrode is placed on the back below the neck when the arm is in the bath, and to the lumbosacral region when the leg is in the bath. The arms may be placed in separate baths, in which case the entire current passes from one arm through the body to the other. The legs up to the knees may be inserted in separate baths, in which case the current passes from one leg to the other through the pelvis. These different hydro-electric methods have a wide range of therapeutic indications and deserve the most careful study. Where both feet are placed in the same bath-electrode, if sodium chlorid or sodium bicarbonate are added to the water the entire current will traverse the water and the tissues of the patient will not be affected. In this case it will be necessary to reduce the conductivity of the water as much as possible so that the path of least resistance will be through the parts of the body immersed in the bath. We recommend that experiments be made with the different bath-electrodes so that their value in therapeutics may be properly appreciated.

123. After static methods, as a means of general electrification, the electric bath stands first in importance. No one today questions its powerful, invigorating, and refreshing action; but to administer it with benefit and without danger, the electric conditions must be carefully studied and

thoroughly understood. Centuries ago, animal electricity was utilized in this manner to combat the evil effects of rheumatism, scrofula, and various cachexiæ. Time has only served to increase confidence in its curative powers, and each succeeding year witnesses some new extension in the field of its practical utility. With a few elementary principles well fixed in the mind, with a clear knowledge of the physiological action of the different currents on the human system, with the electrical conditions thoroughly mastered, nothing can be more convenient and free from *contre temps* than the administration of an electric bath.

The first points to study are the structure of the bath and the means of charging its contents with electricity. The best
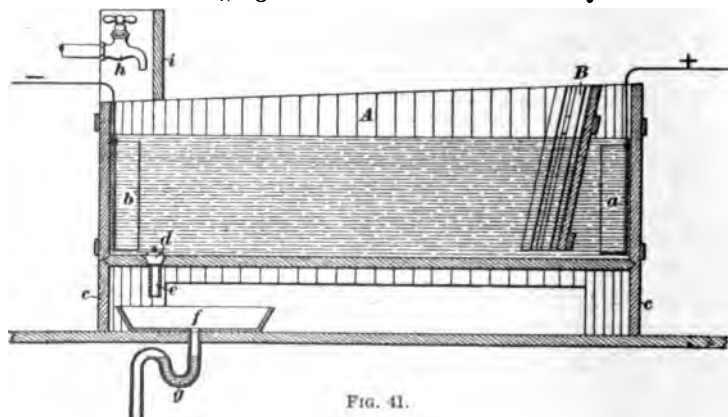
FIG. 41.

materials for constructing a bath for electric purposes are wood and porcelain—porcelain is for various reasons to be preferred. If made of metal, the electricity will travel along the metal, instead of through the patient and through the water. For the same reason, the fewer electrodes attached to the bath the better, because they simply serve to attract the current from the patient. The bath must be effectively insulated; it must not be in metallic connection with the earth. The waste-pipe can be connected to the bath by 4 or 5 inches of rubber tubing. The faucets supplying hot and cold water are not directly connected with the bath, and may be placed 4 or 5 inches above its margin.

124. Insulation.—With a current of moderate amperage and low E. M. F., insulation is not necessary. When, however, one desires to make use of all the therapeutic properties of the electric bath, insulation becomes a necessity. Complete insulation is not only possible but very easily attained. The porcelain bath is placed on four insulating supports. These may be made of either glass or vulcanite. The faucets for hot and cold water must have no connection with the bath, and are placed 4 or 5 inches above its margin. The bath is emptied into a supplementary sink, which is placed close by. A bath thus constructed and located is in no danger of establishing electrical connection with the earth. Fig. 41 illustrates this form of bath. For description see *Accessory Apparatus.*

MONOPOLAR AND DIPOLAR BATHS.

125. The Monopolar Bath.—Electric baths are of two kinds, viz., monopolar and dipolar. In the **monopolar bath,** one electrode is applied to the nape of the neck or to the arm or to some part of the body out of the water. The water of the bath constitutes the other electrode, and very accurately adapts itself to all parts of the submerged body. If the electrode applied to the body outside of the water is made positive, the current will then flow from the electrode into the body. It is therefore evident that in the monopolar bath the whole current employed must pass into the body. The copper electrode, to which a stout rheophore is attached and placed at the foot of the bath, completes the circuit. The whole current diffuses into the water from all parts of the body, to be again concentrated in the foot-electrode, whence it flows to the negative binding-post. The disadvantage of this form of bath is that only moderate currents can be employed, as the electrode applied outside of the water is, of necessity, small. If the current is strong and too concentrated, it will cause pain and produce destructive local electrolytic action.

126. The Dipolar Bath.—The dipolar bath is the one habitually used in practice. It must be completely insulated, and is supplied with two electrodes, preferably of aluminum.

It is useless to plate the electrodes for purposes of appearance, because the current will quickly transfer the plating from the positive to the negative electrode. The electrode at the head of the bath is usually the larger, and measures 18 in. × 12 in. The electrode at the foot of the bath measures 11 in. × 9 in. The shoulders of the patient must be protected from contact with the head-electrode, in order to prevent burning and pain. This is accomplished by placing a wooden framework between the shoulders and the electrode. The wooden framework is illustrated in Fig. 41. The soles of the feet, on account of their poor conductivity, may be placed against the foot-electrode.

Another subdivision of electrical baths is made by the physical qualities of the current employed. The electrical bath may be of the continuous-current type or it may be the alternating; if alternating, it is either a symmetrical or a dissymmetrical current. The dissymmetrical current is obtained from the medical faradic battery. The symmetrical, or sinusoidal, current is obtained from a therapeutic alternator. The direct current may be obtained from a medical galvanic battery or from a light circuit, the latter being the more convenient of the two. The direct current may be interrupted at the will of the physician. In employing either the direct or the alternating current, a good rheostat should be in circuit, so that the current can be under the control of the physician. By means of the rheostat, the current can be gradually turned-on, and when the séance is completed, can be turned off with the same care.

127. Function of the Rheostat.—The rheostat protects the patient against any shock that might be caused by turning the current on or off too quickly. It further enables the physician to control the sensation produced by the current, whether direct or alternating. In using the galvanic current, a milliammeter and a rheostat are both necessary, and should be employed in every administration of the galvanic bath. It is always important to turn the current on slowly, and carefully observe the effects produced on the patient. During the entire administration of an electric bath, the physician

should be in the room, and carefully note the effects produced on the nervous and circulatory systems. The pulse and respiration should be counted and carefully watched during the administration.

128. Available Current.—A question that continually presents itself, and which is of great importance, is What part of the total current passing through the water of the bath passes through the patient? This question, which has been very carefully and minutely examined by Hedley, Jones, Meylan, and others, is best studied by regarding the patient and the water as parallel branches of a divided circuit. Looking at the question in this way, it will be easily understood that the fraction of the total current passing through the patient will depend on the relative resistances of the patient and the water; ordinarily about 25 per cent. Thus, if the milliammeter registers 150 milliamperes, the patient is subjected to a current of about 37 milliamperes. Steavenson and Jones give about 20 per cent. of the total current as the amount passing through the patient. It may again be repeated that the current should always be gradually turned on by the physician himself, and the effects produced on the patient carefully observed. Both electrodes should be covered by the water in the bath, and the whole of the patient's body, with the exception of his head, is also completely immersed in the water.

129. Temperature.—The temperature of the water is also a question of importance, as the higher the temperature the better is its conducting capacity. The more current passing through the water, the less will pass through the body. When the physician can command any current-strength desired, the temperature of the water makes little difference, because it is only necessary to increase the strength of the total current to obtain the required current for the body. The usual temperature of the bath is about 98° F. It is, however, regulated to suit the conditions of the patient. The custom of adding salts or acids to electric baths is to be condemned, particularly when the physician is using a current from Leclanché cells. The salts and acids increase the conducting capacity of the water

and lessen the current-strength passing through the patient. Further, allowing for the therapeutic action of the electric current, the effect of acids and salts in baths is extremely problematical. The usual rule of not taking a bath immediately after a full meal holds also in the case of electric baths. The effects produced by an electric bath are usually exhilarating and refreshing. The patient feels invigorated after the bath, and there is no tendency to take cold.

130. Current-Density.—On account of the large sectional area of the composite conductor in the case of an electric bath, and further, on account of the difference of resistance between the water and the patient, current-density assumes special importance in the administration of electric baths. Of course, current-density is just as important in other electrical applications as it is in the electric bath, but the prejudice existing against electric baths makes it necessary to state plainly and squarely everything connected with them. The electric current flowing through water in a bath or through the human body between the electrodes or along the metallic conductor or in any circuit has been very aptly compared to a girl's hair, "which may be gathered up into a narrow tress or allowed to flow loosely, without changing the number of the constituent parts." Whether flowing loosely or gathered into a narrow tress, the number of hairs remains the same. In the same way, the electric current may be conceived to be composed of a number of lines, which are near together or far apart, according to the current-strength and the sectional area of the conductor through which it is passing. The number of lines of current-strength remains the same whether the current is flowing through a narrow nerve or a piece of muscle of large sectional area. This is very clearly illustrated in Fig. 42.
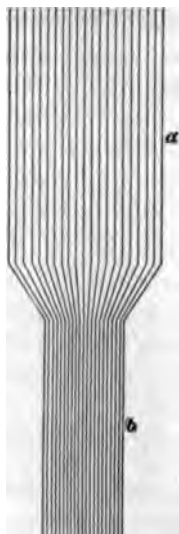
Fig. 42.

THE ELECTRIC DOUCHE.

131. Method of Procedure.—In giving an **electric douche,** the indifferent electrode is placed under the patient's feet, or, if it is desired that the patient be seated, a gluteal electrode is used. The water coming from the rose, or nozzle, constitutes the other electrode, or the active electrode. This is in many cases a very agreeable and very efficient method of electric treatment. One terminal of the battery is connected with the electrode beneath the feet, and the other is attached to the insulated metal terminal of the nozzle, or rose. The electric douche combines the therapeutic properties of the hydriatic douche with those of general and local electrization. The treatment given with any form of current may be either local or general. The water coming from the nozzle renders the skin a better conductor of electricity, and at the same time increases cutaneous irritability, rendering the stimulating action of electricity on the periphery stronger and more effective. The induction-coil currents are very readily applied by means of the douche, and a current-strength perceptible to the patient is easily obtained. With one electrode placed under the feet or under the gluteal region, and connected with one binding-post of the battery or source of supply used, and the other electrode, which in this case is the unbroken stream of water, connected with the other binding-post of the source of supply, the electric current passes through the water-electrode to the patient's body. The metallic nozzle, or rose, is insulated, and is not brought in contact with the patient's body. The unbroken stream or streams of water form part of the conducting circuit, and convey the electric current to or from the patient's body. In this way the electric douche differs materially from the electric vapor or the electric hot-air bath. In these last two electric methods, two electrodes are brought into direct contact with the patient's body. The hot air or vapor do not convey the electric current to the body; they both cause perspiration and heat the skin, and in this way facilitate the action of the electric currents. The indifferent electrode is placed under the patient's feet, and the active electrode on any part of the body the physician

desires to treat. Two covered metallic electrodes are used in the electric hot-air and vapor bath.

132. That water conducts electricity is a well-known fact. The douche may be electrized and the current conveyed to the patient as long as the stream of water remains unbroken. The douche may be composed of a single unbroken stream of water, or a number of streams may be projected from a rose; but an unbroken stream of water and high E. M. F. are necessary in this method of electrical application. In the electric bath no effort is made to increase the conductivity of the water; in fact, it is often a distinct advantage to diminish the conductive capacity of the water, in order to increase the current-strength passing through the patient; but with the electric douche, the aim is to bring all the current one can to the patient's body. The stream of water forming the douche is part of the electric current, and it should be made as good a conductor as possible. This can be done by elevating its temperature, and by the addition of some salt or acid. The nozzle, or rose, is held at a distance from the body, which permits the water-pressure to deliver to the patient an unbroken stream.

HOT-AIR AND VAPOR BATH.

133. The **electric hot-air and vapor bath** combine the effects produced by Turkish and Russian baths with the known therapeutic qualities of the current of electricity employed. The vapor-bath produces copious perspiration; the surface of the body is bathed in moisture and sweat, all the glands of the skin are stimulated to increased action, there is marked cutaneous hyperemia, and the body is rendered a very active electrolyte. The electric vapor-bath is given at a temperature varying from 90° to 105° F. The hot-air bath is well borne at a much higher temperature, varying from 100° to 120° F.

134. Summary of Hydro-Electric Methods. — The hydro-electric methods thus far studied are three, namely:

1. *The Electric Bath, Monopolar and Dipolar.* — Either of these is again subdivided by the physical qualities of the current

employed.   The currents employed are the galvanic current,
which may be continuous or interrupted, and the induced cur-
rent, which may be symmetrical or dissymmetrical.   The sym-
metrical, or sinusoidal, current has invaded, within recent years,
those domains of pathology that were once regarded as the exclu-
sive field for the employment of the direct galvanic current.

2.   *The Electric Douche and Spray.*—In this form of treatment,
the stream or streams of water constitutes the active electrode and
conveys the electric current to the patient.   It is a form of treat-
ment adapted to a large number of pathological conditions, on
account of the active manner in which it produces peripheral
stimulation.   The douche alone has long been recognized as an
efficient tonic, alterative, and absorbent.   These valuable thera-
peutic properties are simply augmented in efficacy by the
judicious selection or combination with electric currents.

3.   *The Electric Hot-Air and Vapor Bath.*—From these two
methods of applying electricity, the therapeutic effects of
Russian and Turkish baths are added to the physiological
properties of the various currents acting under the best con-
ditions for their administration.   Hot air and vapor do not
conduct electric currents, but they do diminish cutaneous resist-
ance and facilitate the penetration of electric currents into the
body.   Besides the effects produced by the electric currents
used, the patient receives the benefit of the hydriatic and ther-
mal properties of Turkish and Russian baths.

135.   Treatment of Cavities.—Another method of
hydro-electric treatment, which has been introduced into
electrotherapeutics within recent years by Boudet, of Paris,
has given to the physician a much needed means of combating
and curing certain common and obstinate maladies.   By this
method is meant the hydro-electric douche applied to the
mucous cavities and the mucous canals of the body.   This
method of treatment was quickly utilized in this country, and
much of the knowledge of its therapeutic capabilities is due to
the labor and writings of Dr. M. Cleaves.   The dangers and
difficulties of applying strong galvanic currents to mucous
canals and cavities prevented the use of currents of sufficient

strength to obtain desired results. These dangers and diffi-
culties are now obviated by the use of special electrodes
completely insulated and perforated to allow the passage
through them of a current of water. The electrodes used
simply convey the water and electricity; the water within
the canal or cavity constitutes the true electrode. By means
of a special electrode, illustrated in Fig. 43, direct galvanic

FIG. 43.

Rectal Electrode.

currents of 20 or 30 milliamperes can be employed within
the rectum without any danger of destructive electrolytic
action. The electrode is inserted well within the bowels,
and the water allowed to flow until the rectum becomes
filled. The electric current is turned on simultaneously with
the flow of water. The water in the bowels constitutes the
electrode, and diffuses the current to all parts of the rectum.
This powerfully stimulates the peristaltic action of the intes-
tines, and is one of the most efficient means of treating chronic
constipation and the various affections involving the mucous
and muscular layers of the large and small intestines. Alter-
nating currents cause non-striated muscle-fibers to contract
when they are not pathologically altered. It has been proved
by direct experiment that non-striated muscle-fibers, when in a
paretic condition, such as obtains in intestinal obstruction,
respond little if at all to alternating currents, while vigorous
contraction can be produced by the galvanic current or the
galvano faradic. Celiotomy should never be performed for
intestinal obstruction until the physician has made at least
two thorough trials, separated by an interval of 3 or 4 hours,
of the direct galvanic current applied by a special rectal elec-
trode. During each séance two or three voltaic alternatives
should be practiced. Cases have been reported by well-known
observers where surgeons were ready to open the abdomen for
intestinal obstruction, in which one séance of galvanization,

applied as directed above, with a few voltaic alternatives, pro-
duced in a short time a copious fecal evacuation. The rationale
of the galvanic current in effecting a cure in these often deplor-
able cases is easily comprehended, and in presence of a case of
intestinal obstruction should never be forgotten.

136. Treatment of the Rectal Mucosa.—Inflamma-
tion and ulceration of the rectal mucosa are simply and speedily
cured by the hydro-electric douche. The electrode used is very
simple, and the technique easily carried out in the physician's
office, when a toilet-room is within convenient distance. If the
hydro-electric douche had no other use than in the treatment of
chronic constipation, its technique should be familiar to every
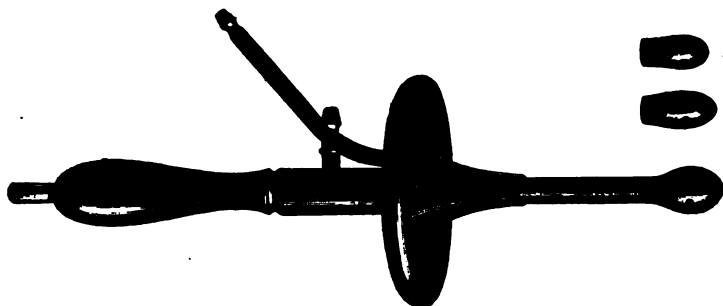
FIG. 44.

Vaginal Electrode.

physician. Cases of constipation, due to atony of the bowels
and diminished glandular secretion, are more speedily and
scientifically cured by the hydro-electric douche than by any
other known remedial agent. To the water used it is always
necessary to add 1 per cent. of common salt. Medicated
solutions of copper, zinc, or silver may also be employed in
this manner. These various salts in solution are driven into the
mucosa by the cataphoric action of the constant current. In
the accompanying illustration, Fig. 44, is shown a vaginal elec-
trode invented by Dr. M. Cleaves, and which is much used in
treating pathological conditions of the vagina, uterus, and other
pelvic organs. The electrode, through a canal in the center,
conveys the water and also the electric current. The vulcanized
disk prevents the escape of water until the vagina is completely

distended.   A current of from 20 to 40 milliamperes is gener-
ally used.   It is easily seen that, with the vagina well distended,
the electric current comes in contact with the entire vaginal
mucosa and diffuses itself through all the pelvic organs, healthy
or diseased.   The vaginal electric douche is of real value in the
treatment of vaginal, uterine, and ovarian troubles.   The treat-
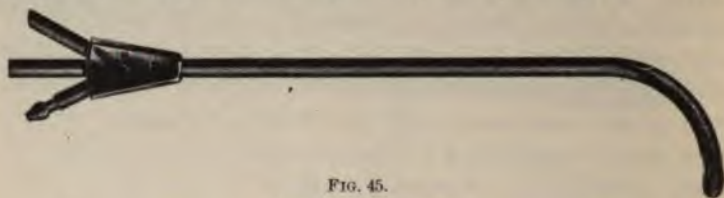
Fig. 45.

Male Vesical Electrode.

ment causes no pain, and is rather agreeable than otherwise.
Of course, the current must be gradually turned on through a
rheostat and turned off with the same care.   It constitutes a
safe means of beginning electric treatment in the gynecological
diseases of debilitated and nervous patients.   Inflammatory
affections of the uterine canal, ulceration of the os tincae,
relaxed vaginal walls, and weakened pelvic structures in
general, are very conveniently treated by the vaginal electric
douche.   The temperature of the douche is regulated to suit
the sensations of the patient.

137.   Interior of the Bladder.—The accompanying illus-
trations, Figs. 45 and 46, show electrodes for administering the
galvanic current to the interior of the bladder.   Fig. 45 is for the
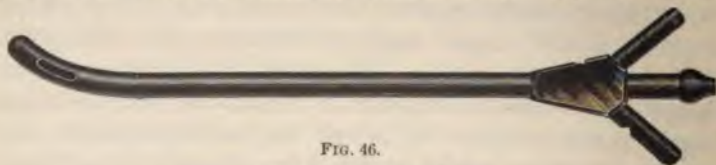
Fig. 46.

Female Vesical Electrode.

male bladder, and Fig. 46 for the female bladder.   For a long
time the induced current has proved itself a valuable agent in
treating paretic and nervous affections of the bladder, but it is
only lately that the galvanic current could be employed in

sufficient strength to be efficacious. From 20 to 30 milli-amperes are used in the interior of the bladder. Very good results are obtained in chronic inflammatory conditions, with thickening of the mucous lining, accompanied by glandular atrophy. Vesical weakness and atrophy are much benefited by the direct current applied by means of the vesical douche.
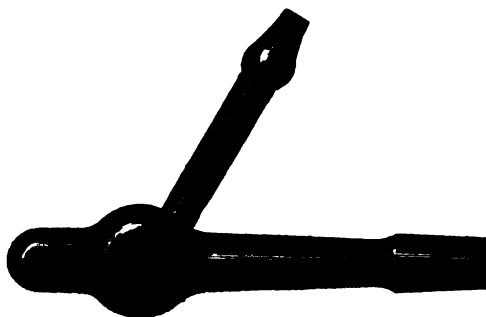
FIG. 47.

Nasal and Aural Electrode.

Catarrhal diseases of the nose and nasopharynx are much relieved or entirely cured by the electric douche. In atrophic nasal catarrh, the diseased glands are soon modified in their function, and the nutrition of the mucous membrane is improved by each treatment. It is found serviceable, in catarrhal troubles of the nose, to add various medicaments to the water used. Among these, cupric sulfate is perhaps the best. Cases of atrophic catarrh of nose and throat have been reported cured, with complete return of the sensation of smell. For treating

FIG. 48.

Post-Nasal.

nasal and aural affections, the electrodes illustrated in Figs. 47 and 48 are used. The conducting material of the electrode is metal, well insulated with gutta-percha. From 3 to 10 milli-amperes are used, and the séance lasts long enough to pass about 3 pints of water through the nasal cavities.

PHYSIOLOGICAL EFFECT OF ELECTRIC BATHS.

138. The Water-Bath.—Any study of the properties of electric baths involves a sharp distinction between the purely thermal and hydriatic effects produced and those properly belonging to the special form of current that the physician may see fit to use. The water-bath, at a temperature ranging from 95° to 105° F., increases the circulation and retards tissue metamorphosis. It is calming in all febrile conditions, and produces sedation in irritable constitutions when all symptoms of fever are absent. An increased amount of blood is brought to the surface of the body; internal organs are relieved of congestion, and are permitted to perform their functions under more nearly normal conditions. The cutaneous glands are slightly stimulated, and eliminate from the system increased quantities of effete material. The action of the hot-air, or Turkish, bath and the vapor, or Russian, bath is much more emphatic, and has a wide field of utility in various morbid processes.

139. Effect of Electric Baths.—The physiological effect of the electric bath may be summed up as follows: Respiration is diminished by dipolar; the temperature is slightly lowered by monopolar; metabolism is promoted considerably by dipolar, slightly by monopolar; and the secretion of urine is increased. The appetite and digestion are improved, the genital functions are stimulated, circulation and nutrition are benefited, sleep is notably restored, and new vigor is imparted to the mental and physical faculties. In short, the electric, and especially the alternating, bath is credited by all with a powerful, invigorating, and refreshing action on the human frame. When a course of baths is given for tonic effects, the interrupted currents will give the best results. If cataphoric and electrolytic effects are desired, the continuous-current bath is used.

140. Gout, rheumatism, lumbago, and sciatica have been successfully treated by both currents. If the alternating current causes pain, the direct current should be employed. In disorders of the circulation, among which Raynaud's

disease may be mentioned, the electric bath, local or general, is the best known treatment. Weak currents are used to build up the nutrition of the parts diseased. Good results are obtained in Raynaud's disease, even after gangrene has supervened. The negative pole is applied over the diseased area, and the positive pole on the lumbosacral region. The object of treatment is to increase the circulation in the diseased member. Weak galvanic currents serve the purpose best. In the local form of bath, the hand or foot affected is placed in a mild saline solution, which then becomes the active electrode, the indifferent electrode being placed on the spine. The galvanic current promotes absorption, accelerates the sluggish circulation, and increases the nutrition of the diseased member. The same results are accomplished in the general electric bath.

141. Rickets.—Very good results have been reported from Italy by Sagretti and Tederchi in the treatment of **rickets** by the electric bath. They ascribe the rationale of the treatment to the nutritive effects of the bath. Steavenson and Jones have also obtained striking results in the treatment of the same disease. After a few applications the general appearance of the patients is changed for the better: appetite and digestion improve, and the little invalids, from a condition almost bordering on spinal paralysis, regain rapidly the power of locomotion.

142. Anemia and Chlorosis.—The electric bath will often render good service as a general tonic and sedative in the course of treatment of **anemia** and **chlorosis**. True, these diseases are most conveniently treated by iron, arsenic, and purgatives, but it is well to know that the action of these valuable agents may be rendered more effective by the judicious use of electric baths.

143. Demedication.—The direct current has been used in bath form in the treatment of gout in the belief that biurate of sodium, through electrolytic action, was removed from the body. During the passage of every galvanic current through the tissues there is always electrolytic action, but this does not

signify that biurate of sodium is eliminated from the body. In gout, the direct current does good by building up the tissues and increasing the tone of the nervous system. The alternating current acts as a general tonic. The direct-current bath has been used to remove mercury, lead, and silver from tissues impregnated with them, but with no success. Althaus reports a case of argyria in which electric baths were persevered in for some time with absolutely no results on the stained tissues. Mercury has been found on the negative electrode of the bath when treating patients that had just gone through a course of mercurial inunctions for syphilis. It is most likely that the mercury came from the surface of the patient's body.

The subject of demedication has not received much scientific attention since the communication of Pocy to the French Academy in 1855. No practical results have been obtained since this date, and the question is still *sub judice.*

144. Medicated Solutions.—If it has not been possible to remove various medicaments from the body by the cataphoric action of the direct current, medicines dissolved in a bath have been made to penetrate into the system, where they exercised their therapeutic qualities. Syphilis, gout, and other maladies have been treated and benefited in this manner. Chronic rheumatism, rheumatoid arthritis, gout, and diabetes are four diseases for which a judicious selection of currents and proper attention to detail in a course of electric baths will accomplish more than massage, medicaments, change of climate, or all of them combined. When the joints are painful and swollen, the galvanic current is the one indicated. As a general tonic to promote elimination and give tone to the nervous and muscular systems, the interrupted-current bath is the best. The electric vapor-bath is indicated in plethoric subjects, where elimination of effete material requires special attention. On account of its tonic and invigorating properties, the interrupted current should be administered with the vapor-bath.

145. Symmetrical Alternating Current.—The symmetrical alternating current employed in the bath has given very good results in various diseases treated by Gautier

and Larat. Among the diseases treated by them were "lymphatism," obesity, eczema, and diabetes. As might be expected, the hydriatic and electric properties of the bath are much used in the treatment of diseases of the nervous system. Neurasthenia will yield to a course of electric baths, when central galvanism and static methods have failed. Diphtheritic and other forms of toxic neuritis are conveniently and effectively treated in the electric bath. Weak mental states following exhaustive maladies from any cause, such as influenza, typhoid, and malarial fevers, begin to improve after the second or third application.

146. Summary.—In summing up, it may be said that the electric bath, water, vapor, or hot air, finds its greatest field of usefulness in depressed and irritable conditions of the nervous system and in diseases characterized by perverted nutrition. Chronic rheumatism, rheumatoid arthritis, and diabetes are common diseases in the treatment of which electricity is worth more than all other remedies combined. Among the different methods of applying the various currents in the treatment of those diseases, it is not easy to assign a fixed place to the electric bath. The physician, to obtain the best results, must have a clear conception of the properties of the water-bath, the hot-air bath, and the vapor-bath. With these properties well fixed in his mind, the further treatment of the case calls for a judicious selection of the form of electricity required to combat the symptoms of the disease to be treated. In the treatment of these diseases, whose march under the usual medicinal and mechanical treatment is steadily forwards, galvanization, local or general, is frequently needed. Static methods render valuable service, and have a wider range of use than all other methods combined. In its turn, faradization, local and general, meets special indications, and will be employed by the physician when its known therapeutic properties are required.

147. Change of air, massage, tonics, alkalis, salicylates, and dietetic treatment are all faithfully tried by the physician in the treatment of these chronic and painful diseases. In chronic

rheumatism and rheumatoid arthritis, after carefully applying the above-mentioned methods of treatment, the physician usually has, for all his trouble, a patient very much deformed, full of aches and pains, with little or no hope of ultimate recovery.   It is conservative and within clinical testimony to state that the result in these cases would be diametrically opposite had electricity been properly used in the beginning, and its use continued until the body gave every evidence of healthy functions.   No one form of electricity will carry the patient all through the treatment of either chronic rheumatism or rheumatoid arthritis.   The direct and alternating currents applied locally to combat special manifestations or generally to affect the entire system will also be found useful.   Static methods cover a wide range of indications.   Direct and alternating currents may be applied to the body either by the ordinary electrodes or by the water-bath.
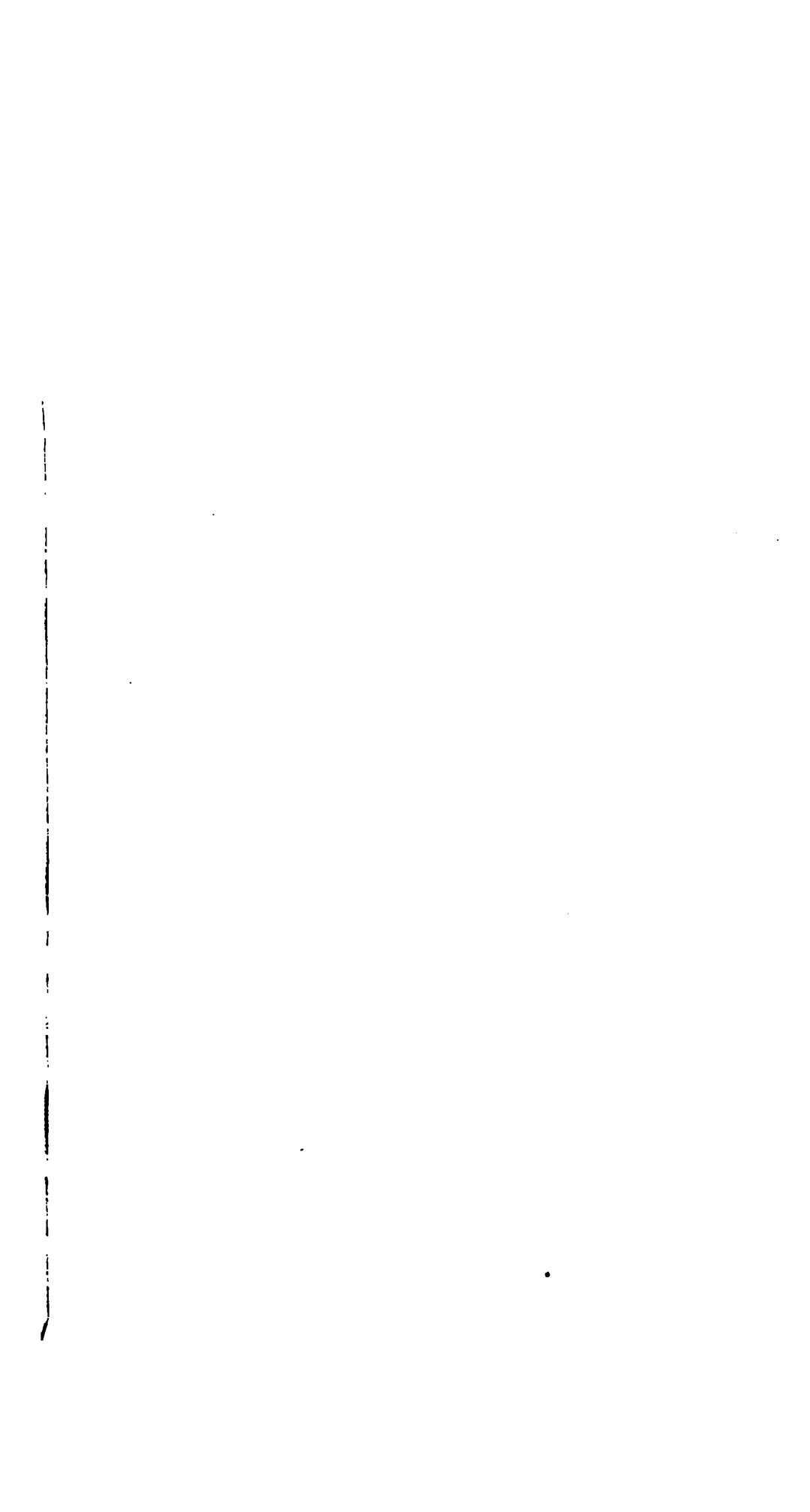
A SERIES OF QUESTIONS

It will be noticed that the questions contained in the follow-
ing pages are divided into sections corresponding to the sections
of the text of the preceding pages, so that each section has a
headline that is the same as the headline of the section to
which the questions refer. No attempt should be made to
answer any of the questions until the corresponding part of the
text has been carefully studied.

Technique and Physiology of Static

AND

Other High-Frequency Currents.

_____ •

EXAMINATION QUESTIONS.

(1)   What purposes does a static machine serve in a physician's office?

(2)   On what does the electrical output of a static machine depend?

(3)   Describe the method of grounding the prime conductors and various electrodes.

(4)   At what distance from the machine and other objects in the room should the insulating platform be placed?

(5)   Describe the method of conducting static currents directly from the machine to the patient.

(6)   How is leakage between the prime conductor and patient detected?

(7)   To whom is the modern revival of static currents due?

(8)   When were static currents first described and what static methods were employed before that time?

(9)   Why are potential alternation and the wave-current called direct interrupted currents?

(10)   How are the plates of a static machine best kept dry?

(11)   Describe the static platform.

(12)   How is the polarity of the static machine recognized?

(13)   Describe the methods of correcting reversed polarity.

(14)   How would you verify the fact that the patient should be insulated in static applications?

(15)   State some advantages of static applications over those made by the galvanic and faradic currents

(16)   Describe the technique for (a) simple positive electrification; (b) simple negative electrification.   ·

(17)   Describe the different methods of interrupting the current between the patient and prime conductor.

(18)   Describe the technique for exercising the muscles of the arm and forearm by potential alternation.

(19)   In simple electrification, before starting the plates to revolve, what should be the relative position of the discharge rods?

(20)   In the wave-current and in the indirect Franklinic interrupted current, before the plates are set in motion, what should be the relative position of the discharge rods?

(21)   How many methods are there for administering the indirect Franklinic interrupted current?

(22)   State (a) the local static methods in the order of their therapeutic importance; (b) the methods of administering each.

(23)   Describe the physiological effects of general electrification.

(24)   What are the principal points to be observed in the administration of the negative breeze?

(25)   What is the difference between the breeze and spray and what property has the static spark that the breeze and spray have not?

(26) How many kinds of sparks are there and what are their relative lengths?

(27) Describe the physiological effects of breeze and spray.

(28) To make frictional sparks more agreeable, how would you proceed?

(29) What precautions should be taken in spark administration and what general rule governs spark applications?

(30) Describe the physiological effects of (a) percussive sparks; (b) frictional sparks.

(31) On what does the energy of muscular contractions produced by static sparks depend?

(32) Describe the methods of using the static cage.

(33) Describe the technique of massage-roller applications.

(34) What is the chief character of spark-gap or Morton currents?

(35) How is the strength of the indirect Franklinic interrupted current regulated?

(36) Describe the method of interrupting the current in (a) potential alternation; (b) the wave-current.

(37) Describe the physiological effects of the wave-current.

(38) On what does the maximum spark-length in the wave-current administration depend?

(39) What is the chief physical property of static electricity?

(40) How is the dosage in static applications regulated?

(41) How is the mildest breeze, spray, or spark administered?

(42) State the essential factors in the regulation of static dosage.

(43) What can you say about the frequency and duration of static applications?

(44) What does every installation for the generation of Tesla-d'Arsonval currents comprise?

(45) Describe the three methods used for the general application of Tesla-d'Arsonval currents.

(46) Describe (a) the general effects of Tesla-d'Arsonval currents; (b) the local effects of these currents.

(47) What can you say about the therapeutic indications of these currents?

(48) How is the energy of static applications (a) increased? (b) decreased?

TECHNIQUE AND PHYSIOLOGY
OF DIRECT CURRENTS.

EXAMINATION QUESTIONS.

(1)   What two facts do we inherit from the controversy between Galvani and Volta?

(2)   To what did Matteucci attribute muscle- and nerve-currents?

(3)   How are the electric currents in nerves, muscles, and glands classified?

(4)   What two important factors should be considered in the application of electric currents to the human body?

(5)   On what does the resistance of the body, as a whole, depend?

(6)   On what does the resistance of the individual tissues of the body depend?

(7)   How did Matteucci demonstrate the conductivity of the different organic tissues?

(8)   Give some instances in which the resistances of individual tissues are of great importance in therapeutic applications.

(9)   State two important questions in the application of electric currents in medicine and surgery.

(10)   In what part of the patient's circuit does the electric current encounter the most resistance?

(11) How may the effects produced in the body by the passage through it of a direct current be classified?

(12) How are the physiological effects of direct currents best studied?

(13) On what do the effects produced on motor nerves and muscles by variations of current-density depend?

(14) Define (a) electrotonus; (b) catelectrotonus; (c) anelectrotonus.

(15) When is a nerve said to be stimulated?

(16) Why are motor-nerve reactions more complicated in man than in the exposed nerve of a frog?

(17) State the normal polar formula and the number of milliamperes required to produce minimum opening and closing contractions.

(18) What is the normal polar formula for the auditory nerve?

(19) What justifies a favorable prognosis in the use of electric currents in tinnitus aurium?

(20) Describe the vasomotor effects produced by the direct current.

(21) Describe the action of the direct current on non-striated muscles.

(22) On what do the effects of the direct current on the brain depend?

(23) What effects are sometimes produced by percutaneous applications of the direct current to the brain, and how are these effects best avoided?

(24) What is it necessary to remember in making a direct-current application to the spinal region with a view to influencing the cord?

(25) How would you demonstrate that part of the direct current applied percutaneously to brain or spinal cord passes through these organs?

(26) What is the basis of electrodiagnosis in diseases of the nervous system?

(27) How many methods are there for exploring motor nerves and muscles?

(28) Which of these methods is preferable when using the galvanic current, and why?

(29) What method is preferable when using the faradic current, and why?

(30) State the apparatus required in the electrical examination of motor nerves and muscles.

(31) Why is the faradic current always used first in electrodiagnosis?

(32) State the important factors in electrodiagnosis of diseases of the nervous system.

(33) Of what does $R\,D$, as described by Erb, consist?

(34) Describe the reaction of (a) Rich ; (b) Remak-Doumer.

(35) Why does a muscle in condition of $R\,D$ respond almost always to the galvanic current when it does not react at all to the faradic current or to static sparks?

(36) State the elementary abnormal electrical reactions.

(37) (a) Into how many groups may the abnormal elementary reactions be arranged? (b) State them.

(38) What do faradic inexcitability, longitudinal reaction, and sluggish muscular contractions signify?

(39) How is longitudinal reaction elicited?

(40) (a) State the different types in the alteration of the contraction curve. (b) To what pathological conditions do they correspond?

(41)   What does the presence of *R D* permit us to affirm?

(42)   With regard to prognosis, into how many stages may *R D* be divided?

(43)   Of what value is *R D* in prognosis?

(44)   Of what value is *R D* in toxic and infectious neuritis?

(45)   State the uses for diagnostic purposes in gynecology of (*a*) the faradic current; (*b*) the galvanic current.

(46)   What is the value of electric resistances in electro-diagnosis?

(47)   State the effects of alternating magnetic fields on metabolism.

(48)   Name the two methods of investigating the relations of electric currents to living animal tissues.

(49)   Why does not a solution of sugar conduct the direct current?

(50)   Define an electrolyte.

(51)   To what is the conductivity of naturally occurring water to be attributed?

(52)   What is the primary action of an electric current when passed through a liquid conductor?

(53)   State (*a*) the anions in physiological fluids; (*b*) the cations in physiological fluids.

(54)   What becomes of the ions when they reach the poles of the electrolytic solution?

(55)   To what is the irritant action of the direct current on the skin due when platinum electrodes are placed directly on the skin?

(56)   In what two respects is the application of Faraday's law to the therapeutic uses of the direct current of the utmost practical importance?

(57)   Define cataphoresis.

(58)   How may a good picture of the cataphoric action of the direct current be obtained?

(59)   Describe the technique of galvanococain anesthesia.

(60)   What is the composition of the electrodes generally employed in metallic interstitial electrolysis?

(61)   To what is the difference between the actions at the poles of a direct current applied to living animal tissues due?

(62)   State the essentials of metallic interstitial electrolysis.

(63)   State the three essential requirements in cerebral galvanization.

TECHNIQUE AND PHYSIOLOGY
OF COIL-CURRENTS.

EXAMINATION QUESTIONS.

(1)   What is the difference between pulsating and alternating currents?

(2)   Why is it that the current through the primary faradic coil does not at once attain its full strength?

(3)   Does the current through the primary faradic coil cease at once when its connection with the electric source is broken? Give reasons.

(4)   What changes does the E. M. F. of the primary faradic coil-current undergo when the circuit is broken?

(5)   Why are not the E. M. F.'s of the make- and break-waves in the secondary faradic coil of equal magnitude?

(6)   Why may an ordinary faradic current be considered as interrupted and unidirectional?

(7)   If the positive waves of a faradic current are to be reenforced, what means are available, and how could this result be obtained?

(8)   A diagram of an alternating current-wave being given as in Fig. 7, what information can be derived from it?

(9)   How may induction-apparatus be classified?

(10)   State the purposes for which the 110-volt direct current may be utilized in a physician's office.

(11)   What effect has a condenser on the secondary current?

(12)   How are the voltage and amperage of secondary coils tested?

(13)   Why is the secondary coil made up of different lengths and sizes of wire?

(14)   (*a*) What is the nature of the faradic current as used in medicine?   (*b*) Under what condition is it an alternating current?

(15)   Define tetanic muscular contraction.

(16)   How may the polarity of the faradic current be determined?

(17)   Describe the experiments of Debedat.

(18)   State why the current from (*a*) the fine-wire coil is sedative, and (*b*) that from the coarse-wire coil is stimulating.

(19)   In pelvic diseases, why is the bipolar electrode used?

(20)   What are the special uses in pelvic diseases of the current from (*a*) the coarse-wire coil?   (*b*) the fine-wire coil?

(21)   What method is used, and why, when it is desired to act on the pelvic circulation?

(22)   How do faradic currents stimulate (*a*) the capillary circulation? (*b*) the lymphatic circulation?

(23)   With electrodes of equal size, at which pole are the muscular contractions more manifest with all variations of E. M. F.?

(24)   State Doctor Goelet's theory of the production of sedation by the current from the long fine-wire coil.

(25)   How does Doctor Apostoli explain the sedative effects of the rapidly interrupted current from the fine-wire coil?

(26)   How would you remove fatigue or pain caused by too vigorous or too long faradic applications?

(27)   On what do the vasomotor and sensory effects of faradic currents depend?

(28) What is the main cause of the reduction of E. M. F. in the secondary of the induction-coil?

(29) How much is the available current-strength reduced in making an application through low resistance, say 3,000 ohms, of the current from the long fine-wire coil?

(30) What effect has this resistance, 3,000 ohms, on the current from the coarse-wire coil?

(31) What may be said of electrode resistance in faradic applications?

(32) How does the number of interruptions influence the current-strength of the secondary?

(33) Define galvanofaradization.

(34) Describe the technique recommended by Bordier in the treatment of myopathic atrophies.

(35) In what affections is galvanofaradization the treatment of choice?

(36) What are the two chief properties of direct intermittent currents as described by Leduc?

(37) When and by whom was the sinusoidal current introduced into electrotherapeutics?

(38) To what does Larat attribute the physiological effects of the sinusoidal current?

(39) Describe the experiment of M. Labatut.

(40) Describe the technique of the undulating current in vaginal and uterine applications.

(41) When it is desired to increase the amperage of the sinusoidal current, how is this accomplished?

(42) What apparatuses are necessary in administering the electric bath, and why are they used?

(43) What percentage of the total current passing through the bath passes through the patient?

(44) (*a*) How is the electric douche utilized in making applications to mucous cavities? (*b*) What advantage has this application over those made with metallic electrodes?

(45) How is general faradization applied to children?

(46) In general faradization, where is the current (*a*) most annoying? (*b*) most tolerant?

(47) When are the secondary coils under the maximum inductive influence of the primary coil?

(48) What are the different methods of administering general faradization?

(49) Give a synopsis of the apportionment of the average application of general faradization.

(50) Describe the effect of galvanofaradization on (*a*) motor nerves and striated muscles; (*b*) non-striated muscles; (*c*) sensory nerves.

(51) In the relief of neuralgia, what are the indications for the use of the faradic or sinusoidal current?

(52) What special advantage has the four-celled electric bath of Doctor Schnée?

(53) What is the chief advantage of the sinusoidal current over the current derived from the secondary of the induction-coil?

(54) What are the effects of the sinusoidal current on the nutrition of tissues?

(55) State briefly the therapeutic indications of the sinusoidal current.

INDEX.

All items in this index refer first to the section number,—which is printed on the inside edges of the headlines and is preceded by the printers' section mark ¿,—and then to the page number. Thus, Anions 6 90, means find the paper having ¿ 6 on the headlines and then find page 90.